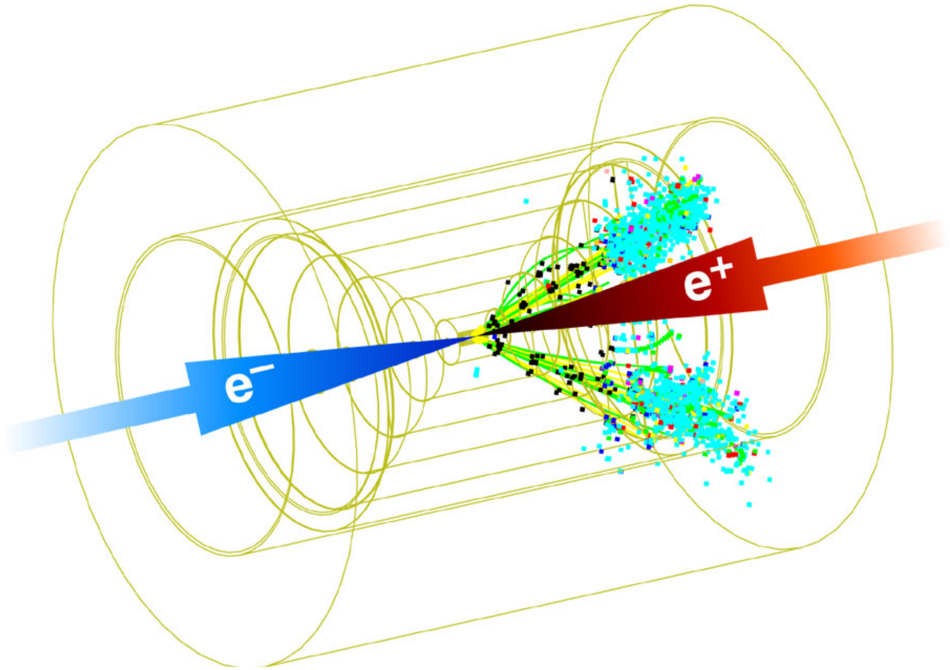
MDI Studies at the ILC
& Test Beam Program at
SLAC's End Station A Facility

Fermilab Seminar, August 29, 2006

M. Woods, SLAC



Outline

Machine-Detector Interface at the ILC

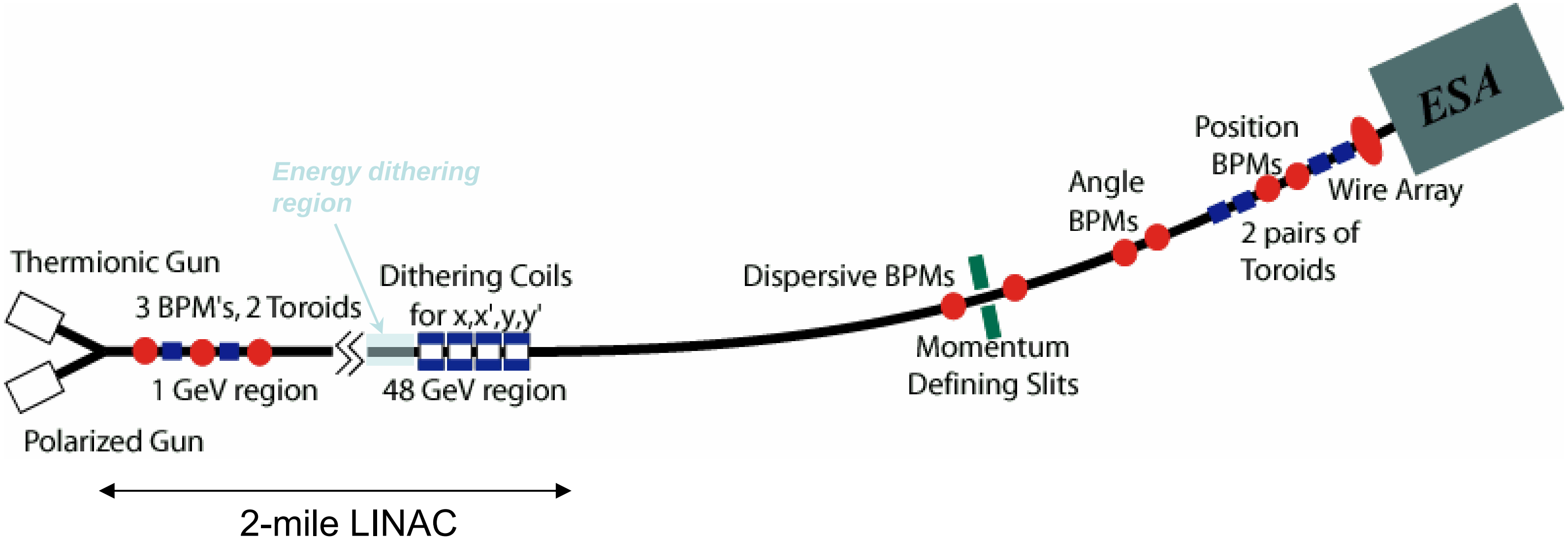
- ❖ **Impact of ILC on Detector design and Physics reach**
  (beyond simply the luminosity and energy reach)
- ❖ **Impact of Detectors and Physics reach on ILC design and parameters**
  - **Collimation and Backgrounds**
  - **(L,E,P) measurements: Luminosity, Energy, Polarization**
  - **Forward Region Detectors**
  - **IR Magnets (solenoid + anti-solenoids, DID—detector integrated dipole)**
  - **IR and Linac Crossing Angles**
  - **EMI (electro-magnetic interference) in IR**

MDI-related Experiments at SLAC's End Station A

- **Collimator Wakefield Studies**
- **Energy spectrometer prototypes**
- **EMI studies**
- **Bunch length measurements**
- **IR background studies**

MDI for SLAC E158

(experiment that measured ~130 parts per billion parity-violating asymmetry in elastic electron-electron scattering)



- ~1/2 experimental DAQ was for beam instrumentation
- experimental control of optics for polarized source laser, implementing feedback from BPM and toroid diagnostics
- automated dithering of beam phase space (energy, x, x', y, y')
- VME crates in polarized source laser room and at 1 GeV, with fiber optic links to ESA DAQ

Parameters for the Linear Collider

ILCSC document, Sept. 30, 2003

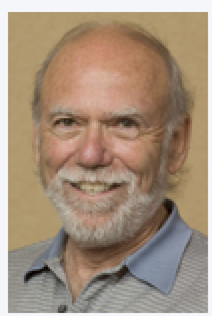
www.fnal.gov/directorate/icfa/LC_parameters.pdf

Baseline Machine Parameters

1. Energy reach: 500 GeV center-of-mass energy.
2. Luminosity: integrate 500 fb^{-1} in 4 years
3. Energy variability: 200-500 GeV
4. Energy stability and precision: sub-0.1%
5. >80% electron polarization
6. 2 IRs
7. 90 GeV operation for calibration at the Z

Director's Corner ILC NewsLine

24 August 2006



Barry Barish

Revisiting the ILC Parameters

An innocent looking little document entitled "Parameters for the Linear Collider" dated 30 September 2003 has to a large extent determined the present baseline design of the ILC. We have used this document as if it were "a requirements document," and the baseline design has flowed down from those requirements. Of course, that document was never intended to play such a critical role, and now that we are entering a period in which we want to optimise cost to performance, we must both understand how the parameters effect cost and how they affect performance (or science potential). For this reason, the International Linear Collider Steering Committee (ILCSC) has recently taken the step to reactivate its parameter group, which will provide us the necessary partner in doing this optimisation, first for the ILC reference design and later for our engineering design.

From T. Maruyama's plenary talk on Backgrounds, at Snowmass 2005

Background tolerance levels

Three levels of criteria:
- Radiation damage
- Pile up
- Pattern recognition

Table is from W. Kozaneck (Collimation Task Force Workshop, SLAC, 2002)
GLD and SiD answers included.

Subdetector	Chrgd trks	γ	n (~ 1MeV)	μ
Vertex detector	6 / mm^2 100/mm^2/tr	300 / mm^2	3×10^9 cm^{-2}y^{-1} 1×10^{10} cm^{-2}y^{-1}	-
Si Tracker	0.2 /cm^2/BX	10 /cm^2/BX		
TPC	2500	1.25×10^6	2.5×10^7	2500
Calorimeter	-	~40000	-	
Muon system	-	-	-	100/cm^2/s

Background simulations

- Simulations from BDS to Dump
  - EGS4, Decay TURTLE, STRUCT, MARS, FLUKA, BDSIM, GEANT3, GEANT4
- Three detectors
- 10 ILC beam parameters
- 2 crossing angles
- Many background sources

- Requires a tremendous amount of work to complete.
- A great deal of work has been done, but much more studies are needed.

Ongoing work at Fermilab using MARS and STRUCT by N. Mokhov. A. Drozhdin, X. Yang et al.

(L,E,P) Measurements at ILC

Electron-Positron Colliders have an advantage of a well-defined initial state, providing good resolving power for precision measurements and elucidating new physics.

Electroweak Physics (examples from *LEP* and *SLC*)

• m_Z, Γ_Z	(LEP-I)	Lumi	Energy	
• m_W	(LEP-II)		Energy	
• $\sin^2\theta_W$	(SLC)		Energy	Polarizaton

Input needed from beam instrumentation

Mandate: provide necessary Beam Instrumentation for the LC physics program!

L,E,P Measurement Goals at ILC

Luminosity, Luminosity Spectrum

- Total cross sections: absolute $\delta L/L$ to ~0.1%
- Z-pole calibration scan for Giga-Z: relative $\delta L/L$ to ~0.02%
- threshold scans (ex. top mass): relative $\delta L/L$ to 1%
  +L(E) spectrum: core width to <0.05% and
  tail population to <1%

Energy

- Top mass: 200 ppm (35 MeV)
- Higgs mass: 200 ppm (25 MeV for 120 GeV Higgs)
- W mass: 50 ppm (4 MeV) ??
- 'Giga'-Z A_{LR}: 200 ppm (20 MeV) (comparable to ~0.25% polarimetry)
  50 ppm (5 MeV) (for sub-0.1% polarimetry with e+ pol) ??

Polarization

- Standard Model asymmetries: < 0.5%
- 'Giga'-Z A_{LR}: < 0.25%

The beam diagnostics measure <E>, <P>. For physics we need to know $\langle E\rangle^{\text{lum-wt}}$, $\langle P\rangle^{\text{lum-wt}}$.

$$\langle E\rangle^{\text{lum}-\text{wt}} \neq \langle E\rangle$$

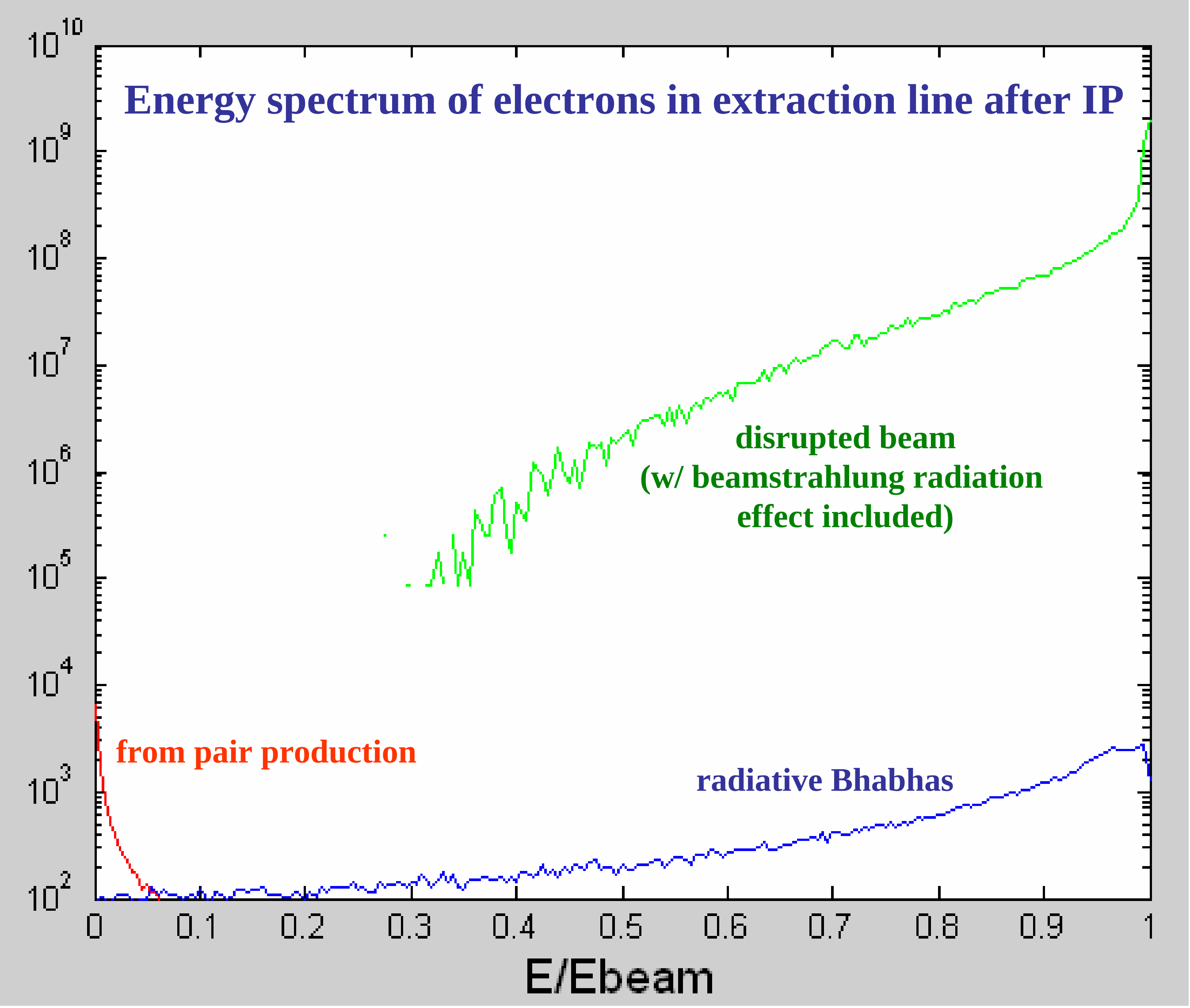
$$\langle P\rangle^{\text{lum}-\text{wt}} \neq \langle P\rangle$$

Strategy is to use a combination of beam diagnostics and physics-based detector measurements. *Need to understand L(E) spectrum and how it is affected from beamstrahlung and energy spread, as well as from initial state radiation.*

➡ **100-200 ppm physics goal for determining $\langle E\rangle^{\text{lum-wt}}$**
<< 1000ppm energy spread
<<< 40,000 ppm energy loss due to beamstrahlung!

Beamsstrahlung at the Linear Collider

~4% of the beam energy gets radiated into photons due to beamstrahlung (at SLC this was 0.1%)



One bias in determining $<E_{CM}>^{lum\text{-}wt}$ is the y-z Kink Instability

Wakefields + Disruption → Y-Z Kink instability

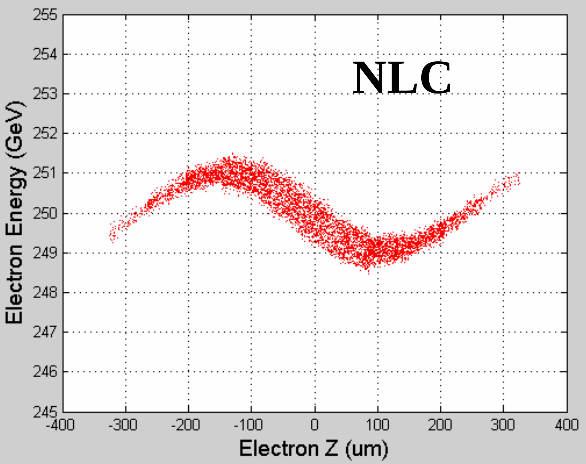
E-Spread + E-Z correlation + Y-Z Kink instability → E_{CM} Bias

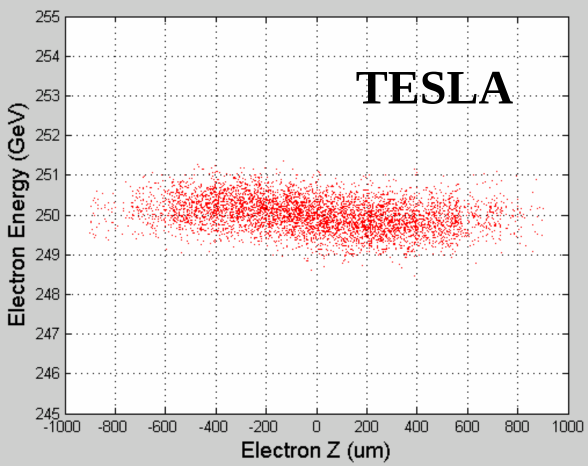
$$E_{CM}^{Bias} = \frac{\langle E_1 \rangle + \langle E_2 \rangle - \langle E_{CM}^{lum-wt} \rangle}{\langle E_1 \rangle + \langle E_2 \rangle},$$

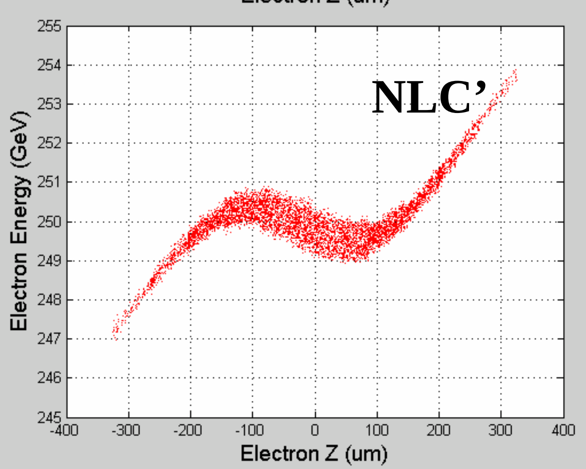
E_1 and E_2 are beam energies measured by the energy spectrometers. (ISR and beamstrahlung are initially turned off for this study.)

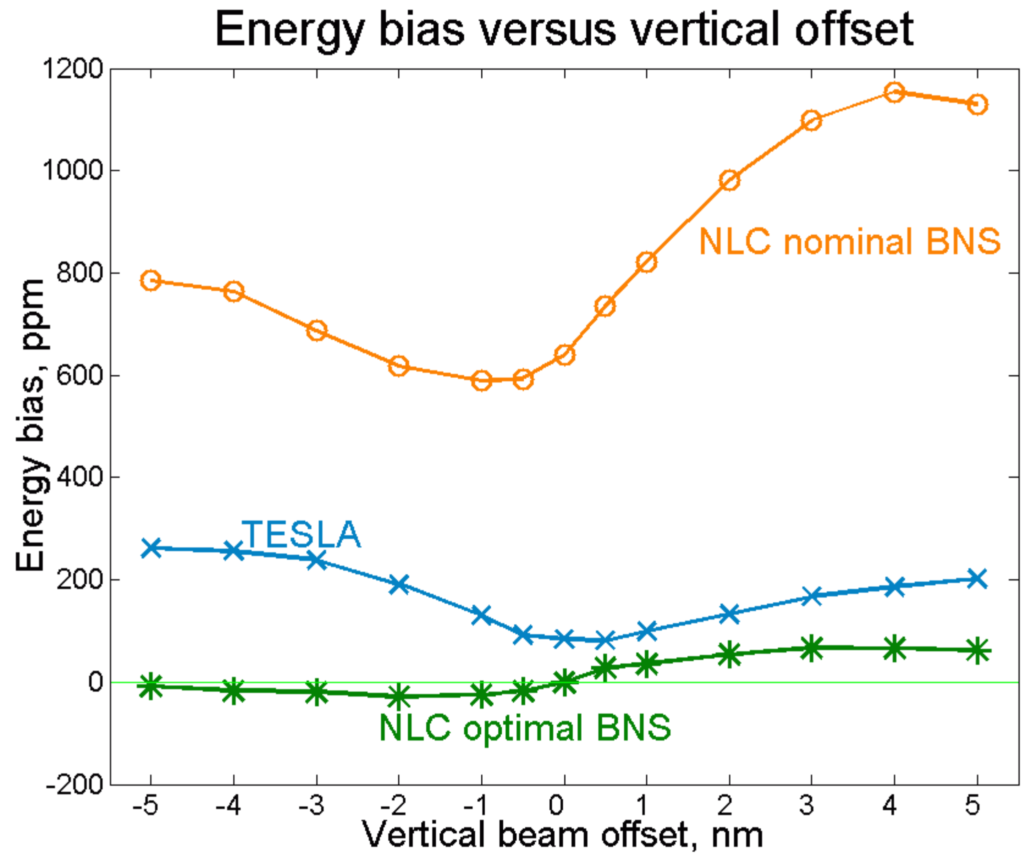
Summary of E_{CM}^{bias}

LC Machine Design	$<E_{CM}^{bias}>$ ($\Delta y = 0$)	$\sigma(E_{CM}^{bias})$ ($\Delta y = 0$)	Max(E_{CM}^{bias}) vary Δy, η_y
WARM-500	+520 ppm	170 ppm	+1000 ppm
COLD-500	+50 ppm	30 ppm	+250 ppm









Summary of E_{CM}^{bias} w/ beamsstrahlung off

LC Machine Design	$\langle E_{CM}^{bias} \rangle$ $(\Delta y = 0)$	$\sigma(E_{CM}^{bias})$ $(\Delta y = 0)$	$Max(E_{CM}^{bias})$ vary Δy, η_y
WARM-500	+520 ppm	170 ppm	+1000 ppm
COLD-500	+50 ppm	30 ppm	+250 ppm
NLC'-500	0 ppm	10 ppm	+50 ppm

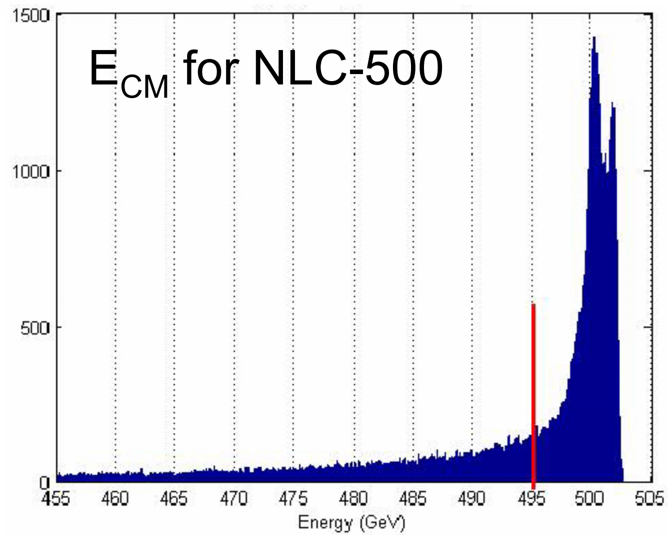
Definition of E_{CM} bias (Beamsstrahlung OFF)

$$E_{CM}^{Bias} = \frac{\langle E_1 \rangle + \langle E_2 \rangle - \langle E_{CM}^{lum-wt} \rangle}{\langle E_1 \rangle + \langle E_2 \rangle},$$

E_1 and E_2 are beam energies measured by the energy spectrometers. (ISR and beamstrahlung are turned off for this study.)

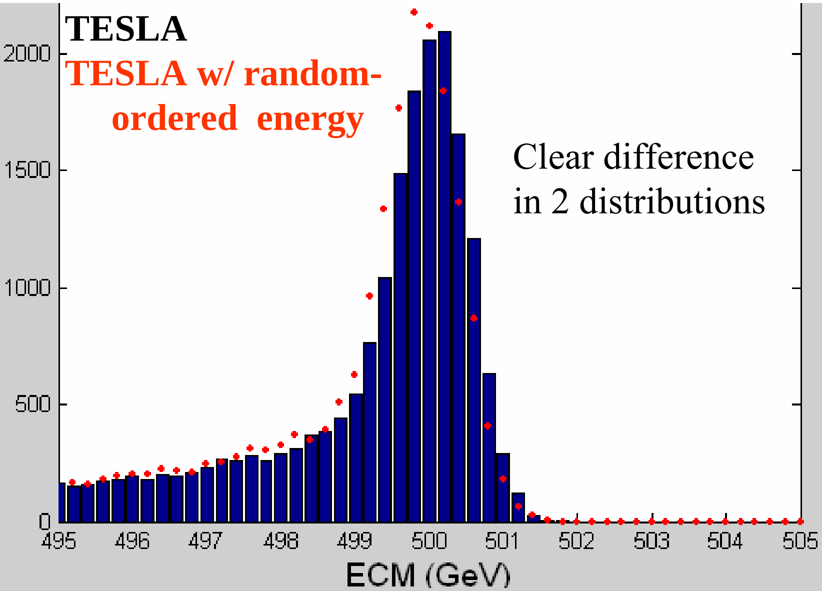
Definition of E_{CM} bias (Beamsstrahlung ON)

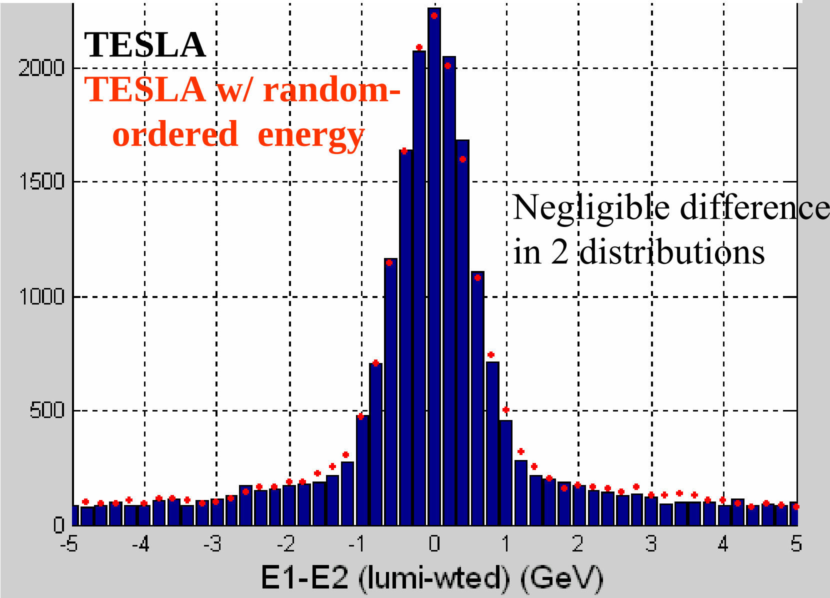
$$E_{CM}^{bias}\Big|_{BSon} = \langle E_{CM}^{lum-wt} \rangle \Big|_{unaltered}^{E_{CM} > Ecutoff} - \langle E_{CM}^{lum-wt} \rangle \Big|_{random E}^{E_{CM} > Ecutoff}$$

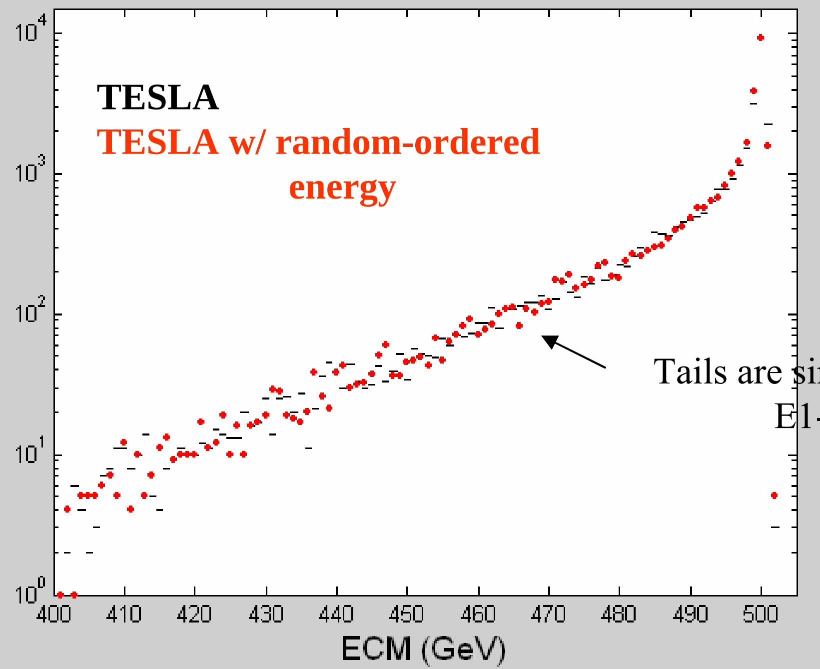


Vary cutoff energy from 480-495 GeV

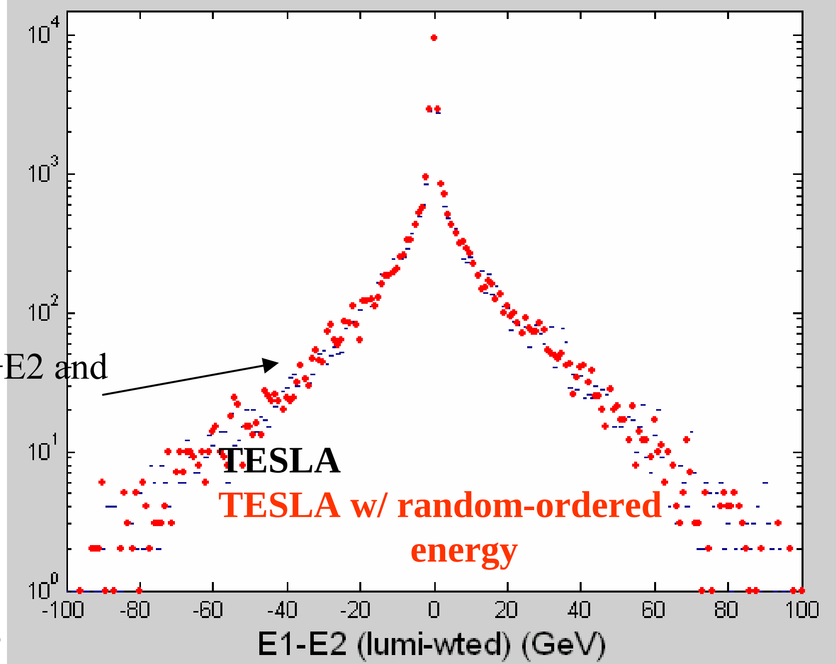
Study of distributions for i) E_{CM} (cannot measure this)
ii) E1-E2 (closely related to Bhabha acolinearity)







Tails are similar in both E1+E2 and E1-E2 distributions



Summary of E_{CM}^{bias} without Beamsstrahlung

LC Machine Design	$<E_{CM}^{bias}>$ ($\Delta y = 0$)	$\sigma(E_{CM}^{bias})$ ($\Delta y = 0$)	$Max(E_{CM}^{bias})$ vary Δy, η_y
WARM-500	+520 ppm	170 ppm	+1000 ppm
COLD-500	+50 ppm	30 ppm	+250 ppm
NLC'-500	0 ppm	20 ppm	<50 ppm

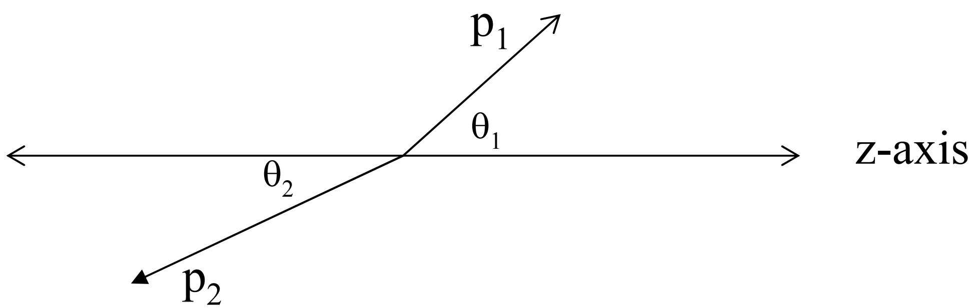
Summary of E_{CM}^{bias} in presence of Beamsstrahlung

LC Machine Design	$<E_{CM}^{bias}>$ ($\Delta y = 0$)	$\sigma(E_{CM}^{bias})$ ($\Delta y = 0$)	$Max(E_{CM}^{bias})$ vary Δy, η_y
WARM-500	+960 ppm	150 ppm	+ 1120 ppm
COLD-500	+150 ppm	30 ppm	+350 ppm
NLC'-500	~0 ppm	20 ppm	<50 ppm

→ Energy spectrometers and Bhabha acolinearity alone are not sufficient to correct for this bias. Need beam dynamics modeling and other input from annihilation data, disrupted energy measurements, …

Physics Measurement of Luminosity Spectrum

Bhabha Acolinearity



$$\theta_A = \theta_1 - \theta_2$$
$$\Delta p = p_1 - p_2$$
$$\frac{\Delta p}{p_{beam}} \approx \frac{\theta_A}{\sin\theta}$$

In (single) colinear photon approximation,

$$\frac{s'}{s} = \frac{\sin\theta_1 + \sin\theta_2 - \left|\sin(\theta_1 + \theta_2)\right|}{\sin\theta_1 + \sin\theta_2 + \left|\sin(\theta_1 + \theta_2)\right|}$$

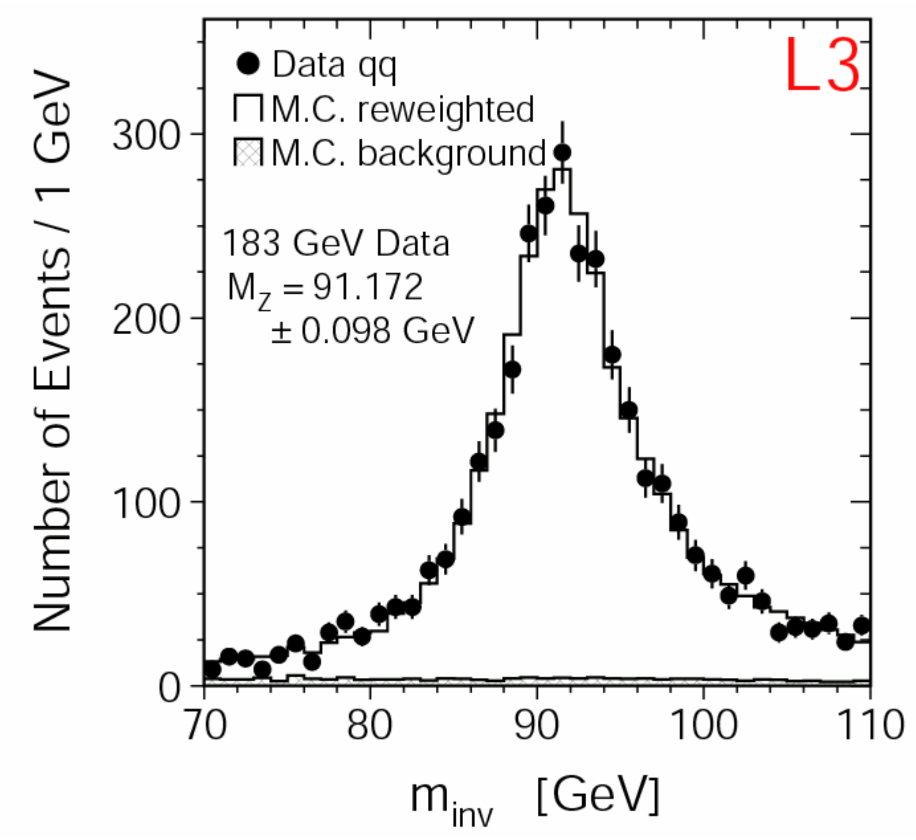
Use Endcap Bhabhas (~120-400 mrad)

Physics Measurements of <E>$^{\text{lum-wt}}$

Use γZ, ZZ, WW events and the known Z and W masses

Use μ-pair events and muon momentum measurements

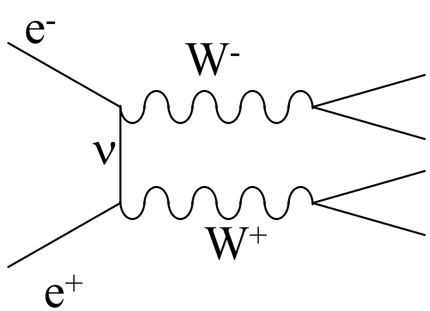
Example of radiative return (γZ) analysis from LEP



Physics Measurements of <P>$^{\text{lum-wt}}$

Use asymmetry in forward W pairs as a polarimeter

Requires low backgrounds <<1%.
(This level of backgrounds is achieved for LEP200 W mass measurements, if require one W to decay to ee or μμ.)
If positron beam is also polarized, can use Blondel-type scheme to fit for beam polarizations as well as physics asymmetry and eliminate sensitivity to backgrounds



- advantage wrt Compton polarimetry is that any depolarization in beam-beam interaction is properly accounted for (need to be above W-pair threshold though)
- disadvantage wrt Compton polarimetry is Compton can achieve 1% accuracy in minutes
- can measure cos(θ)-dependence of the W-pair asymmetry, to allow sensitivity to new physics while providing a beam polarization measurement.

If electron and positron beams both polarized,

$$P^- = 90\%, P^+ = 50\%$$
$$\frac{\delta P^-}{P^-} = 0.25\%, \frac{\delta P^+}{P^+} = 0.25\%$$

$\Rightarrow$

$$P_{eff} = \frac{P^- + P^+}{1 + P^- P^+} = 96.55\%$$
$$\frac{\delta P_{eff}}{P_{eff}} = 0.10\%$$
$$\frac{N_{LR} - N_{RL}}{N_{LR} + N_{RL}} = P_{eff} A_{LR}$$

Can also use 'Blondel scheme' to determine beam polarizations directly:

$$\frac{N_{LL} + N_{LR} - N_{RL} - N_{RR}}{N_{LL} + N_{LR} + N_{RL} + N_{RR}} = P^- A_{LR}$$
$$\frac{N_{RR} + N_{LR} - N_{RL} - N_{LL}}{N_{RR} + N_{LR} + N_{RL} + N_{LL}} = P^+ A_{LR}$$

- just need Compton polarimeters for measuring polarization differences between L,R states
- this technique directly measures lum-wted polarizations

Instrumentation for Luminosity, Luminosity Spectra and Luminosity Tuning

Luminosity

Bhabha LumiCAL detector from 40-120 mrad

Luminosity Spectrum

Bhabha acolinearity measurements using forward tracking
and calorimetry from 120-400 mrad
+ additional input from beam energy, energy spread and energy spectrum
measurements

Luminosity Tuning

IP BPMs

Pair BeamCAL detector from 5-40 mrad

Beamsstrahlung detector?

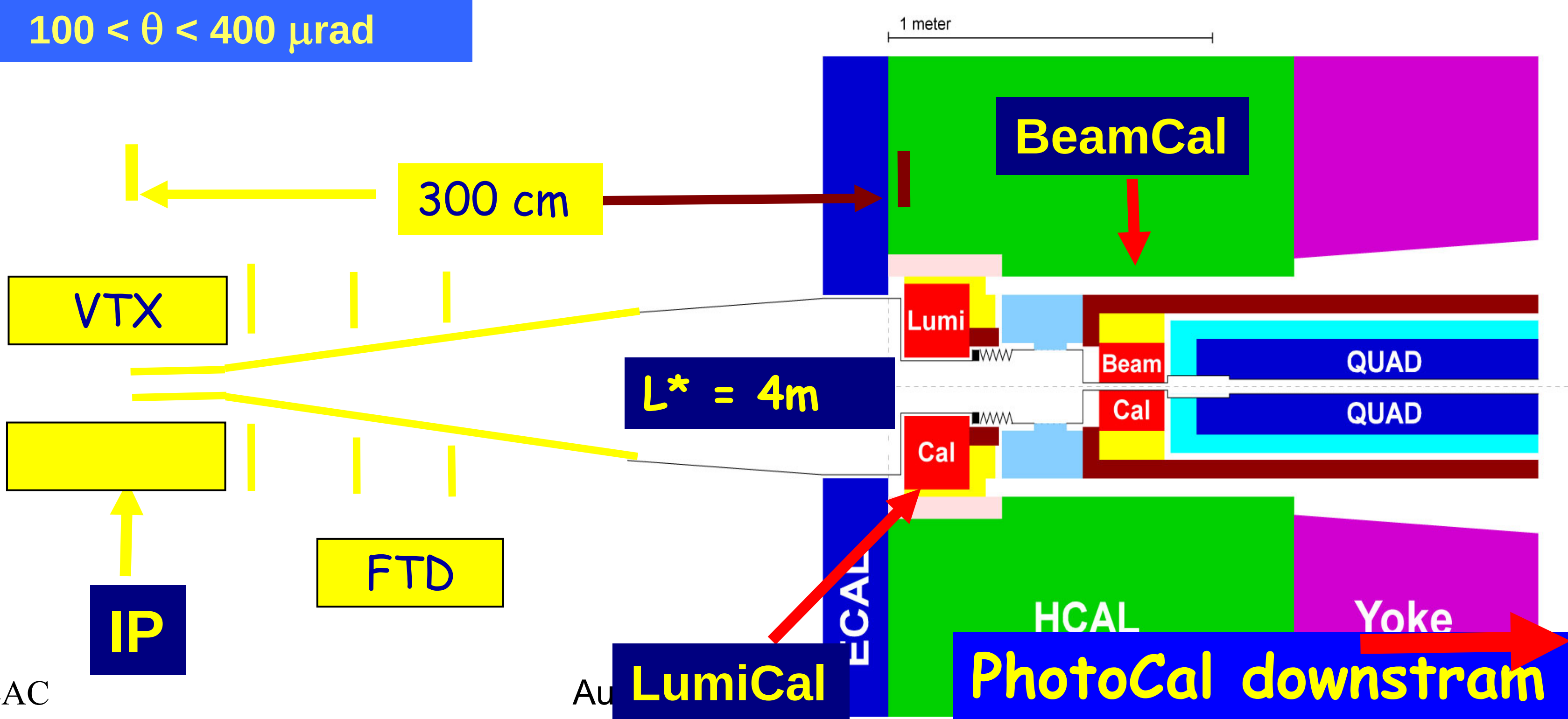
Radiative Bhabhas?

Functions of the very Forward Detectors

From W. Lohmann, talk presented at Snowmass 2005

- Measurement of the Luminosity with precision $O(<10^{-3})$ using Bhabha scattering (see talk by Halina)
- Fast Beam Diagnostics
- Detection of electrons and photons at small polar angles- important for searches (see talk by Philip&Vladimir
- Shielding of the inner Detectors

LumiCal: $26 < \theta < 82$ mrad
BeamCal: $4 < \theta < 28$ mrad
PhotoCal: $100 < \theta < 400$ µrad



Luminosity measurement sensitivities

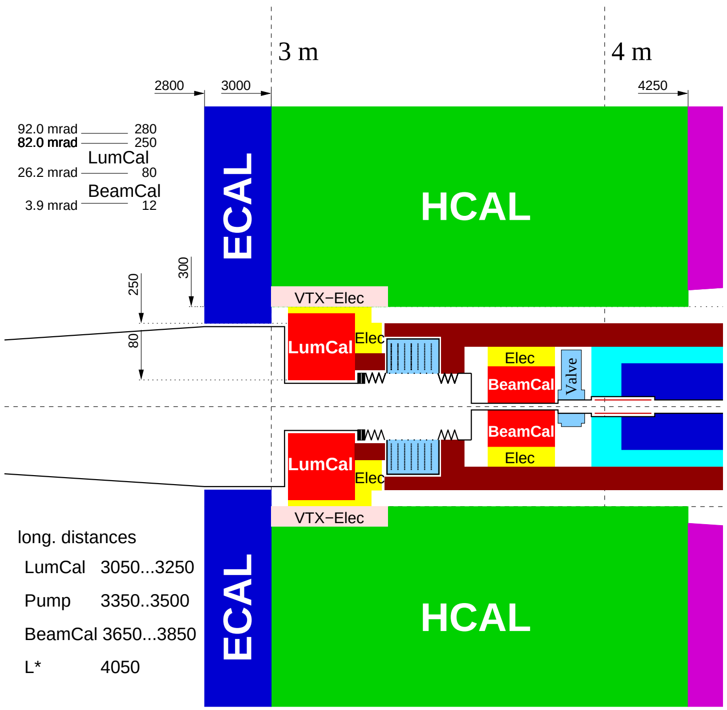
H Abramowicz,Tel Aviv U. and FCAL Collaboration;

Study for Snowmass 2005

$$e^+e^- \rightarrow e^+e^-$$

Goal of FCAL Collaboration – measure L at ILC with accuracy

$$\frac{\Delta L}{L} \leq 10^{-4}$$



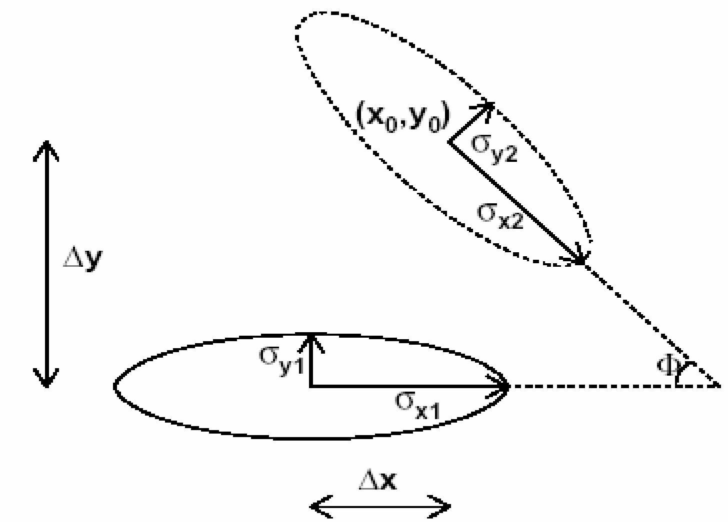
LumiCAL Requirements

$\Delta L/L$	$1.0\text{x}10^{-4}$
Inner radius	4.2μm
Radial offset	640μm
Distance to cals.	300μm
Long. Offset	18mm
Tilt of cal.	14mrad
Beam tilt	0.63mrad
Beam size	negligible

$$(OPAL: \quad \Delta L / L = 3\times 10^{-4}(stat) \oplus 5.4\times 10^{-4}(theo))$$

$$(ALEPH: \Delta L / L = 6\times 10^{-4}(stat) \oplus 6.1\times 10^{-4}(theo))$$

Using Pairs and Beamstrahlung for Luminosity Tuning



7 degrees-of-freedom for colliding bunches:

- individual spotsizes (4)
- relative offset (2)
- relative tilt of bunches (1)

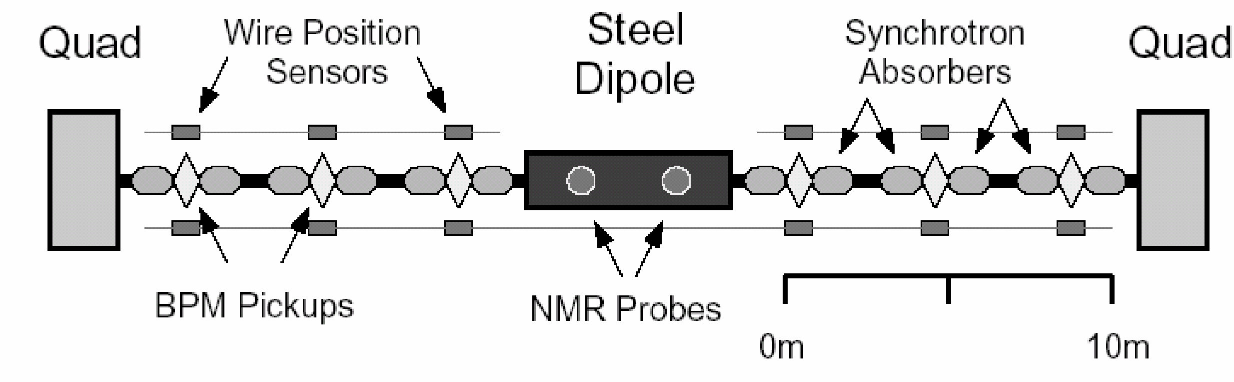
2 promising detector techniques for determining beam offsets and individual beamsizes:

1. Angular distributions of low energy e^+e^- pairs from 2-photon processes
   T. Tauchi and K. Yokoya, Phys. Rev. E51 (1995) 6119-6126.

2. Measuring polarization of the beamstrahlung emitted at angles of (1-2) mrad.
   G. Bonvicini, N. Powell (2003) hep-ex/0304004

2 Energy Spectrometers proposed for ILC

- **"LEP-Type"**: BPM-based, bend angle measurement w/ θ = 3.77

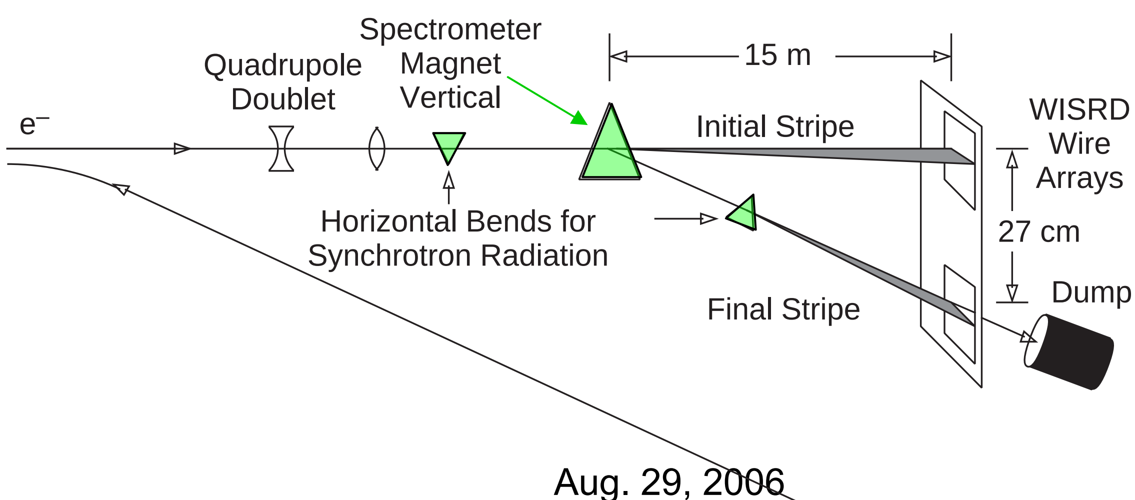


BEAM OPTICAL ELEMENTS
(Electron ELS Shown)

$$\theta = \frac{ec}{p}\int B \cdot d\ell$$

⇒ "upstream"

- **"SLC-Type"**: SR-stripe based, bend angle measurement



⇒ "downstream"

Beam Energy Measurements at LEP-II
(~120 ppm accuracy achieved)

Primary Method: "NMR Magnetic Model"

$$E_b = \frac{ec}{2\pi} \oint B ds$$

- Uses **resonant depolarization (RDP)** data to calibrate at 40-60 GeV
- Uses 16 NMR probes to determine B-fields
- Uses rf frequency and BPM measurements to determine closed orbit length

Additional methods / cross checks:

1. **Flux loop measurements to compare with NMR measurements**
2. **BPM Energy Spectrometer**
3. **Synchrotron tune**

NMR magnetic model, RDP and Synchrotron tune methods can't be used at ILC!

Beam Energy Measurements at SLC

Primary Method: WISRD Synchrotron Stripe Spectrometer

- systematic error estimated to be 220 ppm
- estimated E_{CM} uncertainty 20 MeV

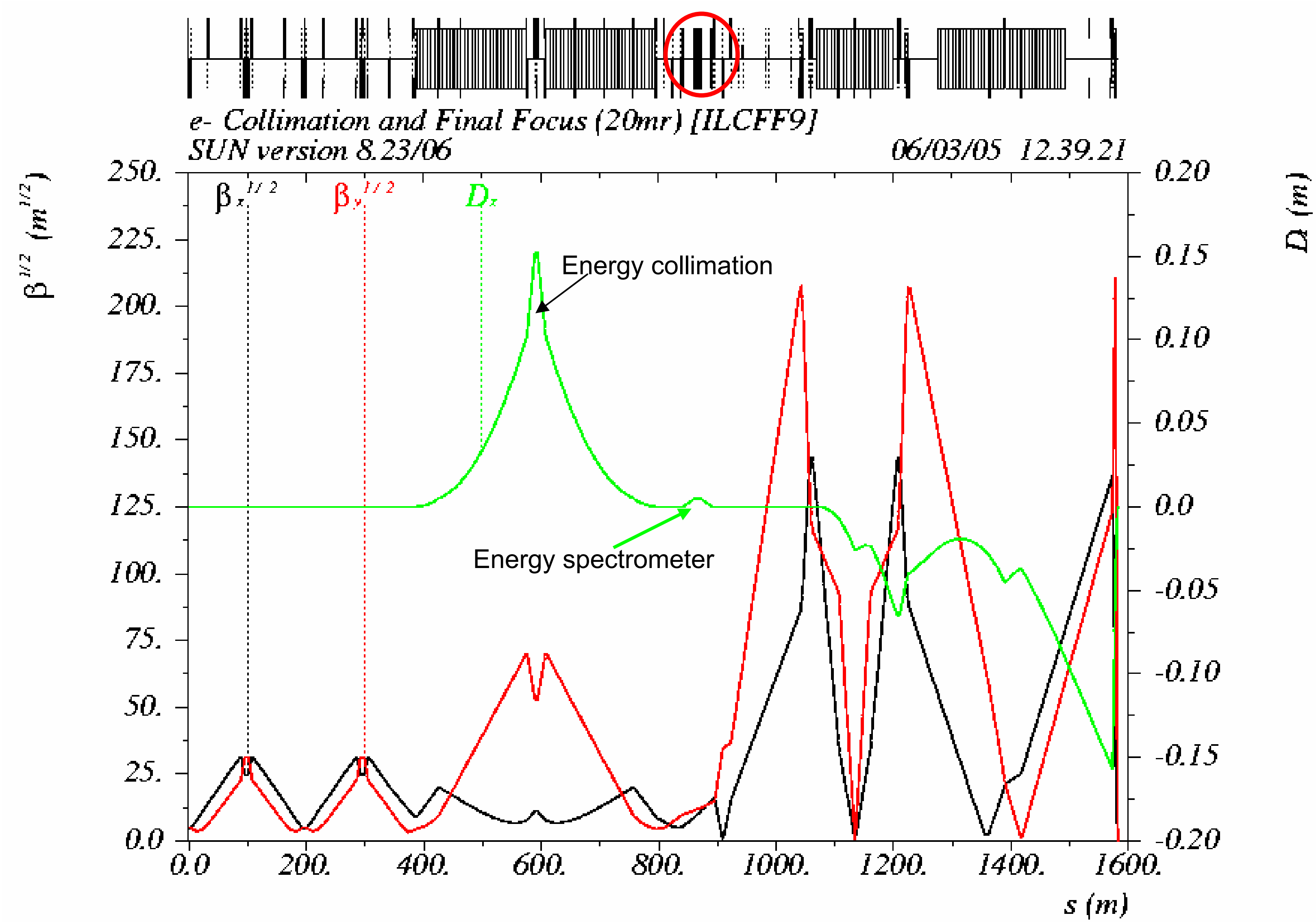
Z-pole calibration scan performed, using m_Z measurement from LEP-I

$\rightarrow$ Determined that WISRD E_{CM} result needed to be
corrected by 46 ± 25 MeV (SLD Note 264);
(500 ppm correction)

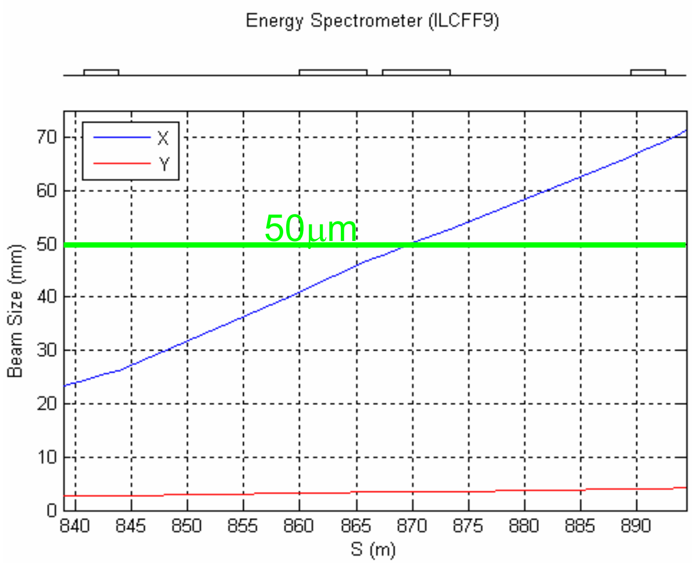
Lessons from LEP-II and SLC:

more than one technique is required for precision measurements!

Upstream E-spectrometer chicane



Upstream Energy Spectrometer Chicane



$$\frac{d\varepsilon}{ds} \approx \frac{\gamma^5}{R^3}\frac{\eta^2}{\beta}$$

Amount of Synch Rad Dammage to emittance

ds = path in bend field of radius R

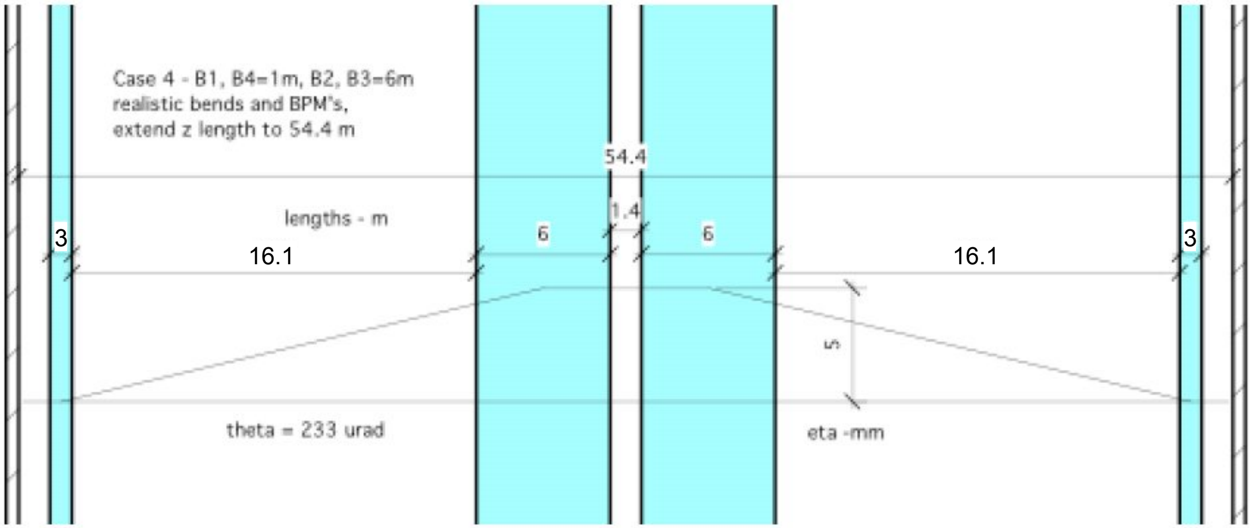
$\gamma = E/m_e c^2$

η= local dispersion

β = local betatron function

Long magnets, low B fields where η is large

- 230 μrad bend angle
  (LEP-II was 3.8mrad)
- 5mm dispersion at mid-chicane
  (100ppm : 500nm!)
- reverse polarity for calibration
- ~55 meters z-space required

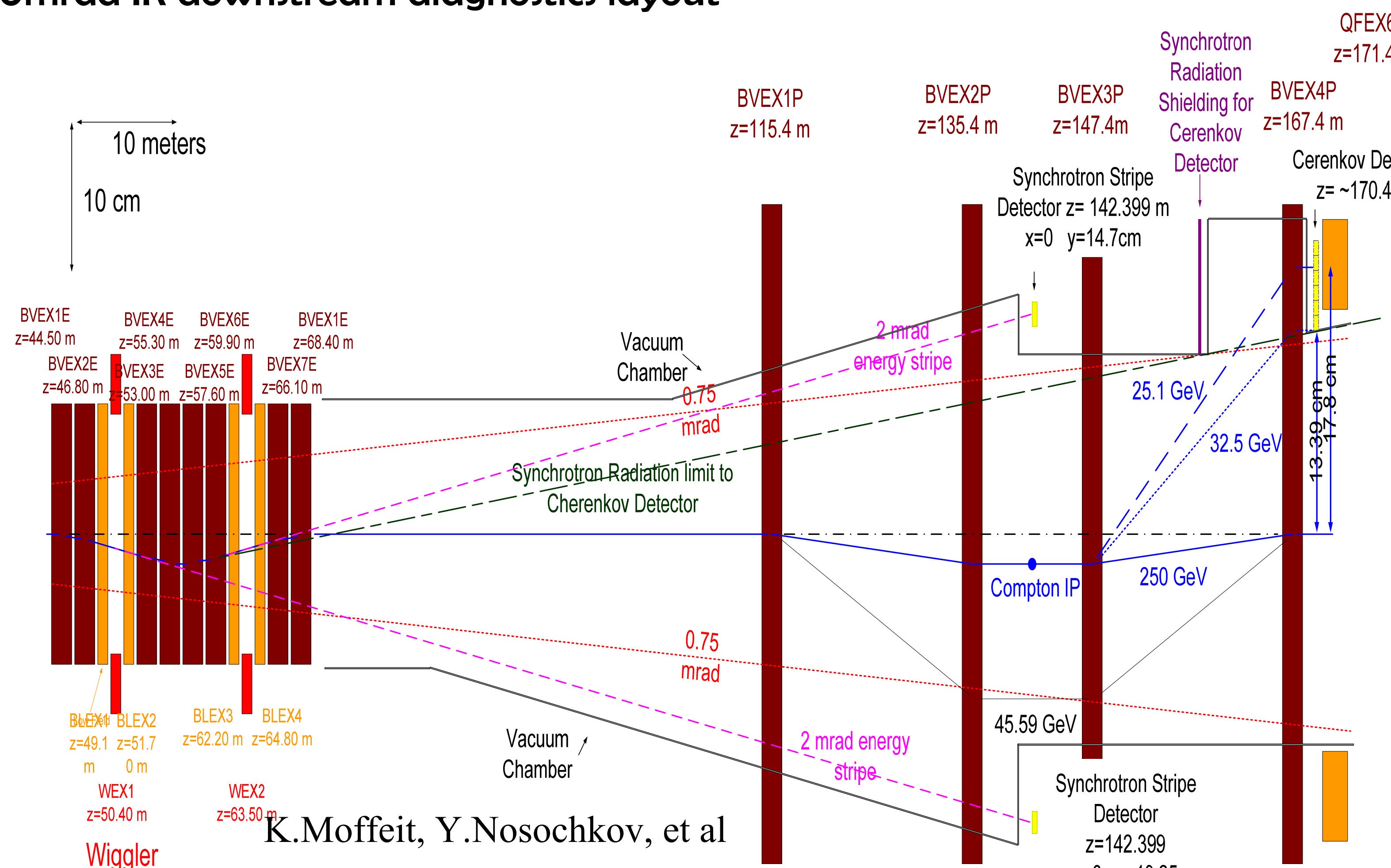


ILC Extraction Line Diagnostics for 20mrad IR

Energy Chicane

Polarimeter Chicane

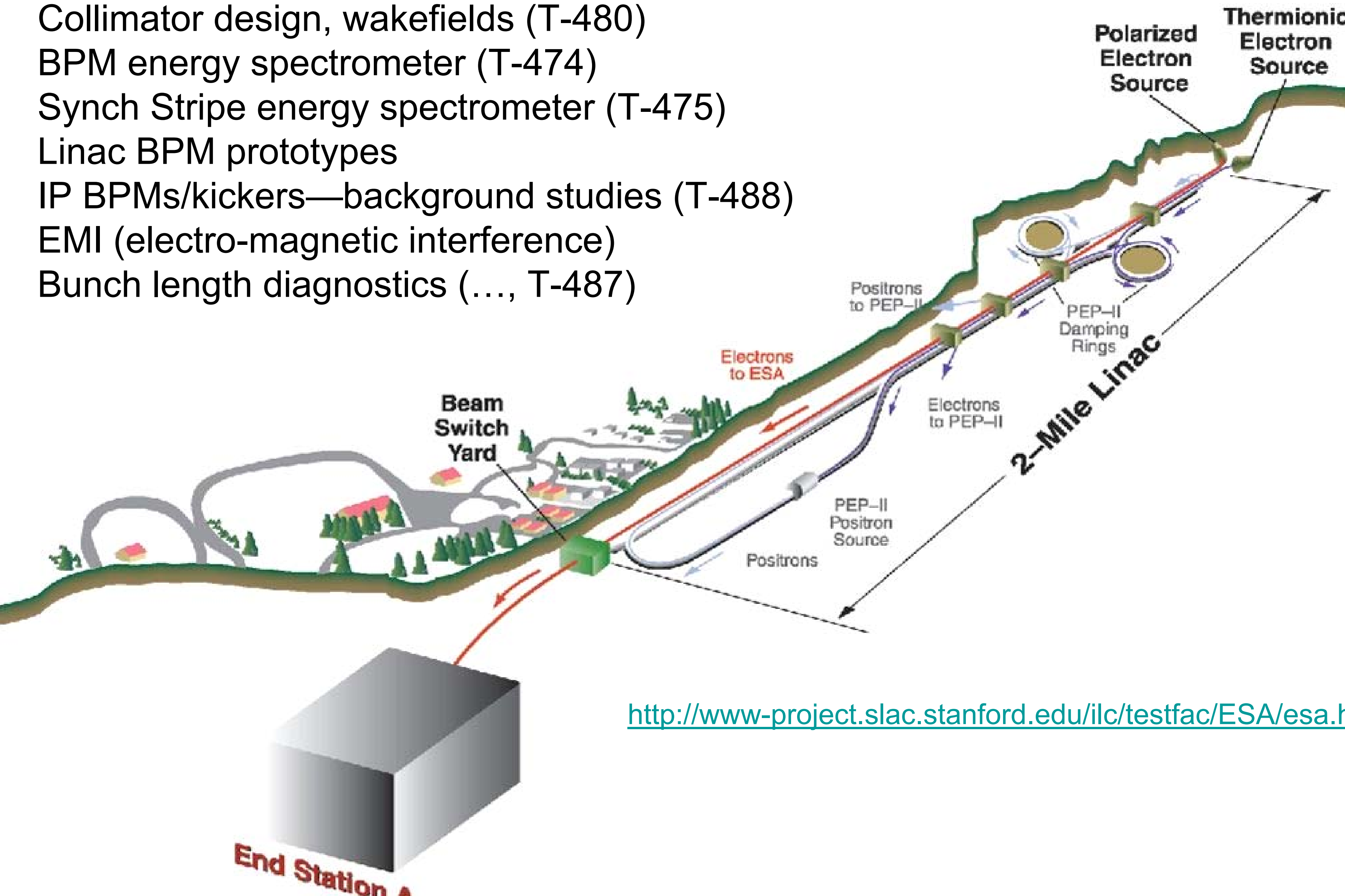
20mrad IR downstream diagnostics layout



K.Moffeit, Y.Nosochkov, et al

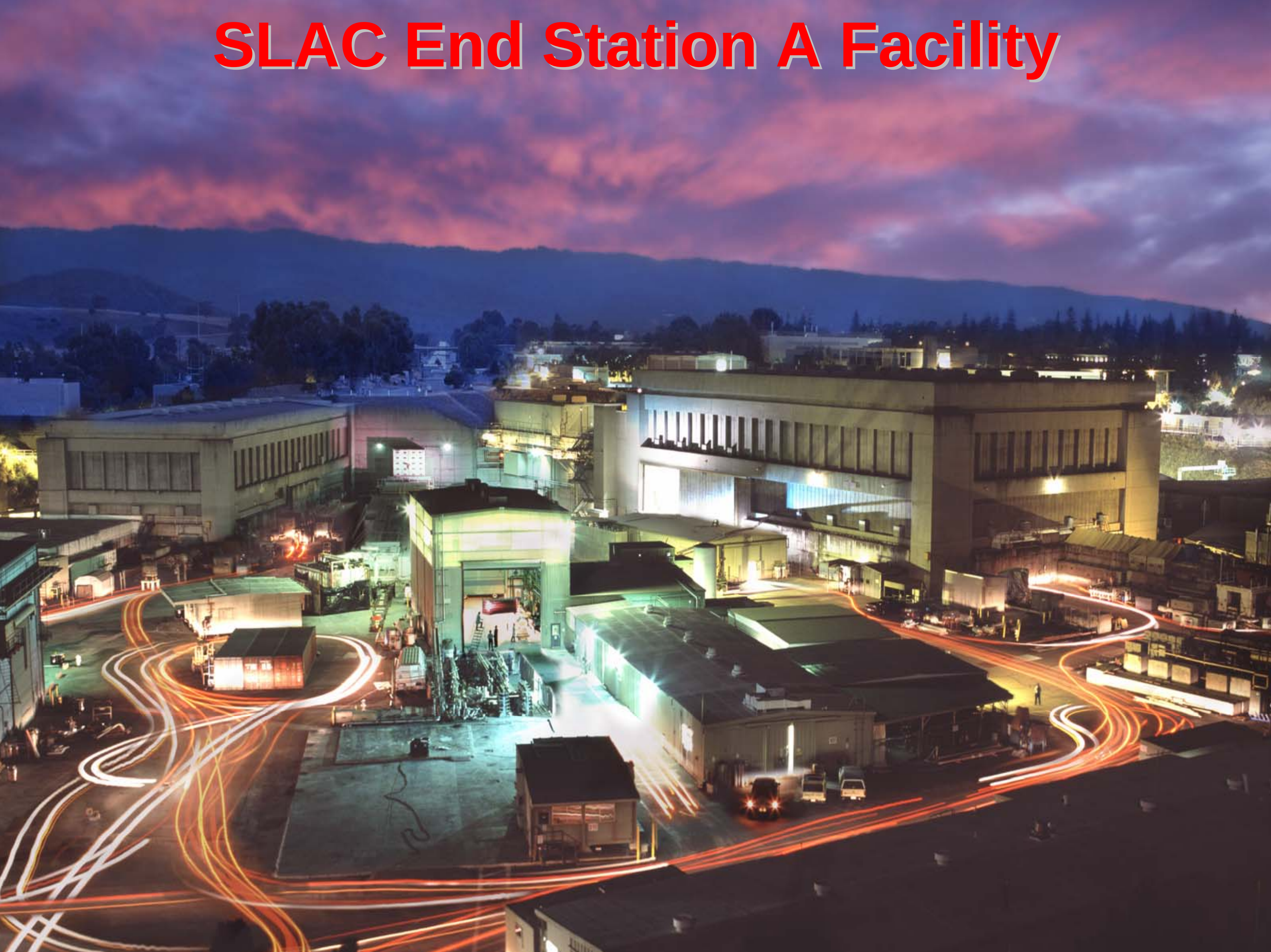
ILC Beam Tests in End Station A

Collimator design, wakefields (T-480)
BPM energy spectrometer (T-474)
Synch Stripe energy spectrometer (T-475)
Linac BPM prototypes
IP BPMs/kickers—background studies (T-488)
EMI (electro-magnetic interference)
Bunch length diagnostics (…, T-487)



http://www-project.slac.stanford.edu/ilc/testfac/ESA/esa.html

SLAC End Station A Facility



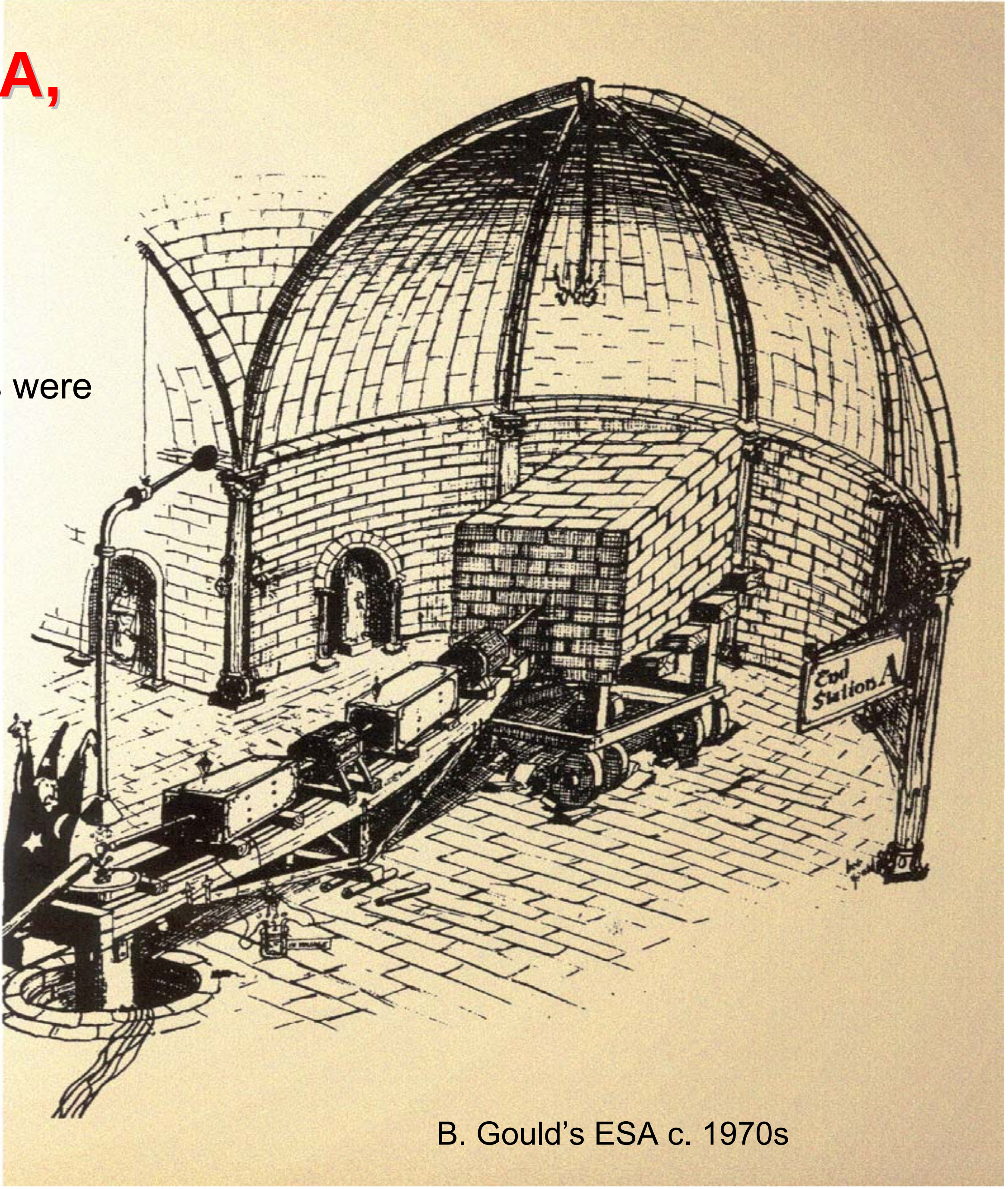
Beam Parameters at SLAC ESA and ILC

Parameter	SLAC ESA	ILC-500
Repetition Rate	10 Hz	5 Hz
Energy	28.5 GeV	250 GeV
Bunch Charge	2.0×10^{10}	2.0×10^{10}
Bunch Length	300 μm	300 μm
Energy Spread	0.2%	0.1%
Bunches per train	1 (2*)	2820
Microbunch spacing	- (20-400ns*)	337 ns

*possible, using undamped beam

Inside ESA,

… 8- and 20-GeV spectrometers were removed for E158 in late ’90s



B. Gould’s ESA c. 1970s

International Linear Collider
at Stanford Linear Accelerator Center

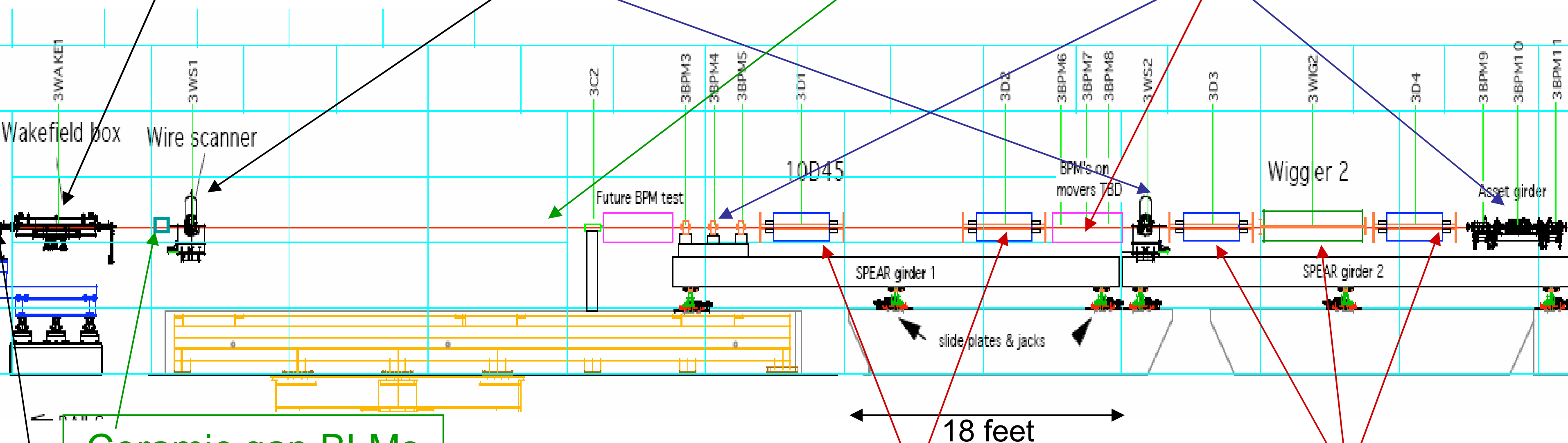
ESA Equipment Layout

Wakefield box

Wire Scanners

“IP BPM” Module

rf BPMs



Ceramic gap BLMs

+ ceramic gap (downstream of 3BPM11, not shown) for EMI studies

Dipoles + Undulator

Upstream

4 rf BPMs for incoming trajectory
1st Ceramic gap w/ 4 diodes (16GHz, 23GHz, 2 @ 100GHz), 2 EMI antennas

blue=April ’06
green=July ’06
red=FY07

+ T-487 for longitudinal bunch profile (location tbd) using pyroelectric detectors for Smith-Purcell radiation

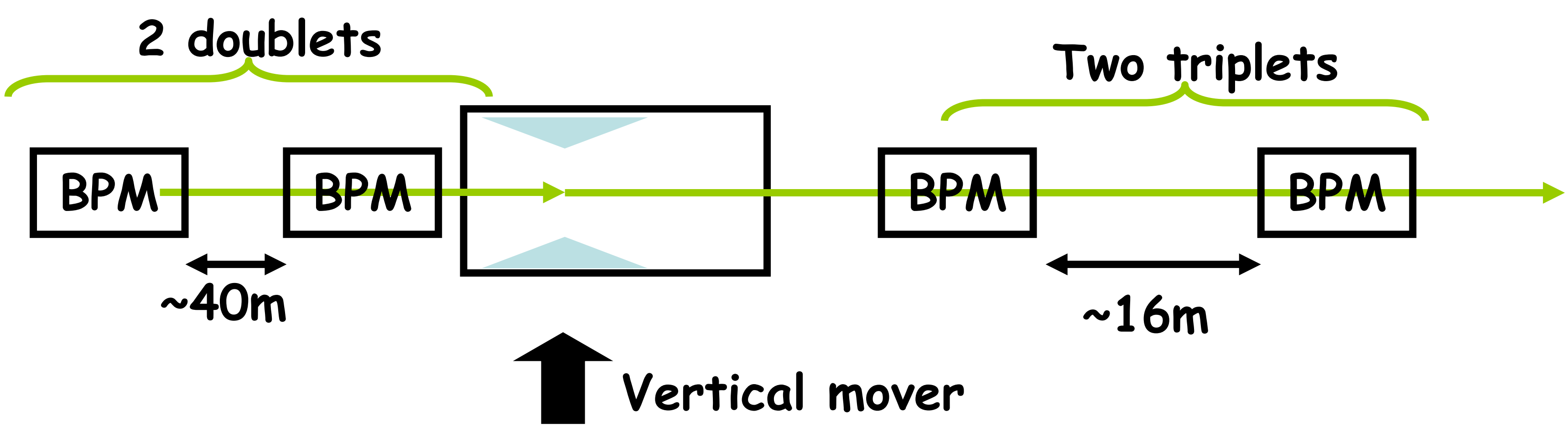
Installation of Beamline Components

T-480: Collimator Wakefields

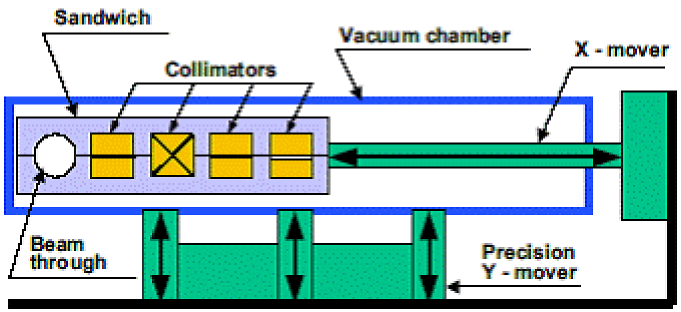
Collimators remove beam halo, but excite wakefields. Goal is to determine optimal collimator material and geometry. These studies address achieving the ILC design luminosity.

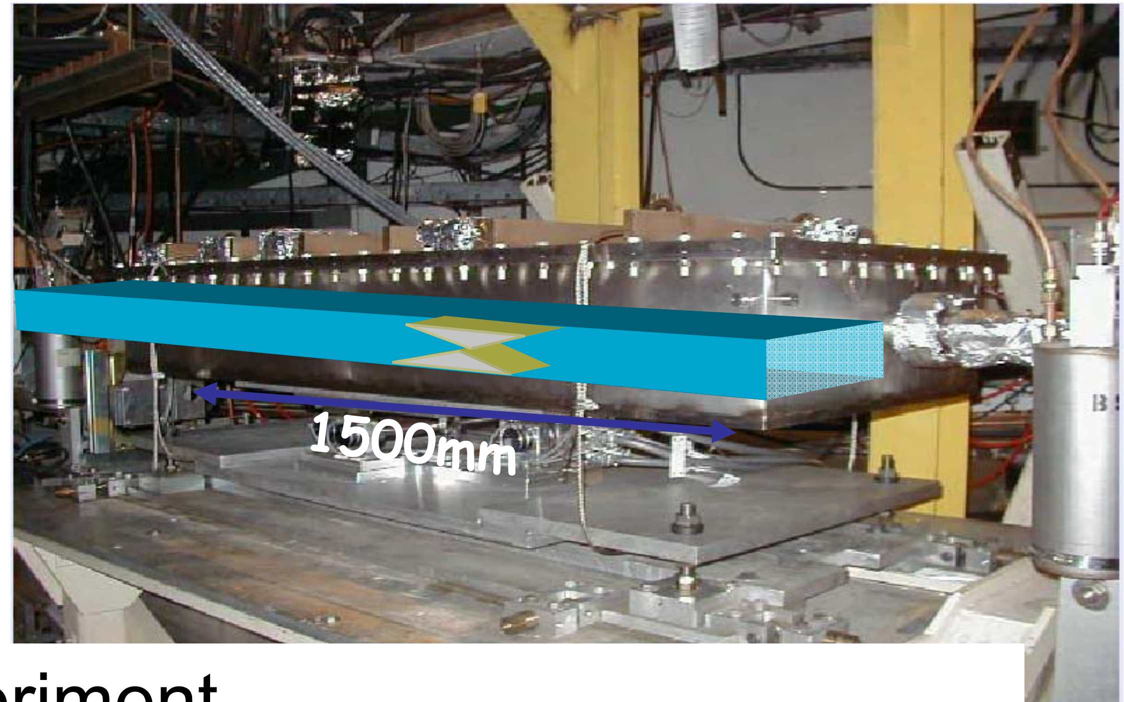
PIs: Steve Molloy (SLAC), Nigel Watson (U. of Birmingham)
Collaborating Institutions: U. of Birmingham, CCLRC-ASTeC + engineering, CERN, DESY, Manchester U., Lancaster U., SLAC, TEMF TU

Concept of Experiment

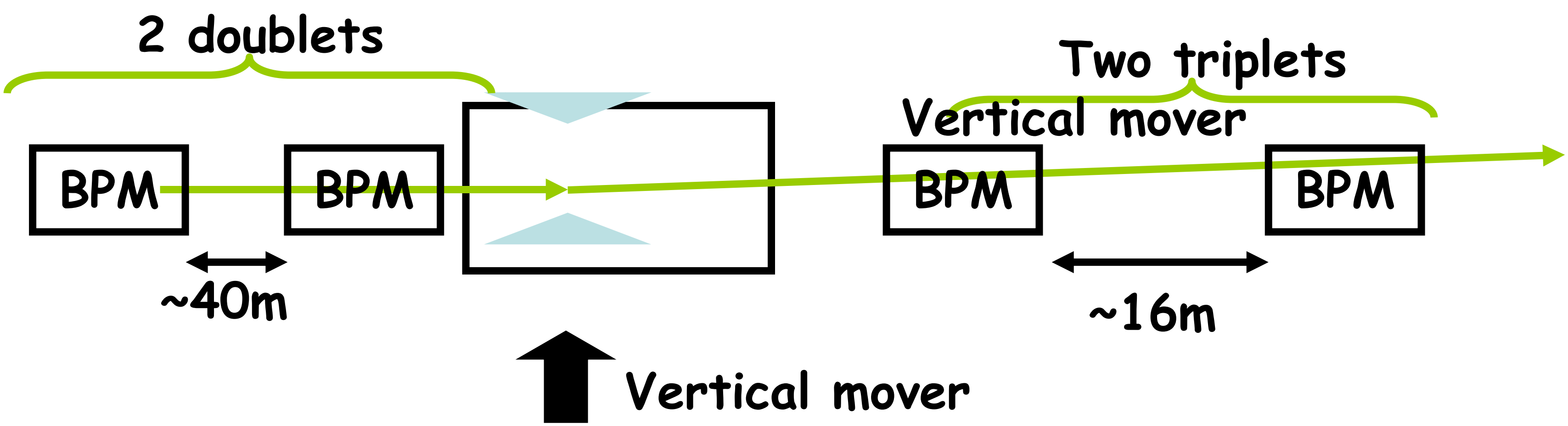


T-480: Collimator Wakefields





Concept of Experiment



T-480: Collimator Wakefields

Slot	Side view	Beam view	
1	α r=1/2 gate	38 mm h=38 mm	α=335mrad r=1.9mm
2			α=335mrad r=1.4mm
3	L=1000 mm		α=335mrad r=1.4mm
4	7mm		$\alpha=\pi/2$rad r=3.8mm

Collimators to study resistive wakefield effects in Cu

Slot	Side view	Beam view	
1	7 mm	38 mm h=38 mm	$\alpha=\pi/2$rad r=1.4mm
2	208mm		α=168mrad r=1.4mm
3	28mm		$\alpha_1=\pi/2$ rad α_2=168mrad r_1=3.8mm r_2=1.4mm
4	159mm		α_1=298mrad α_2=168mrad r_1 =3.8mm r_2 =1.4mm

Collimators to study 2-step tapers in Cu

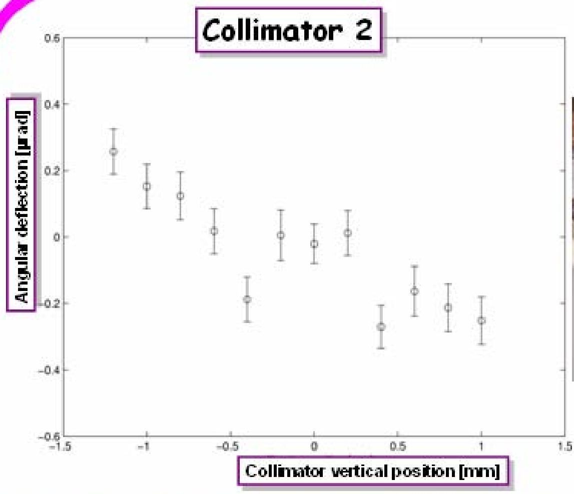
8 new collimators were fabricated in UK

T-480 Preliminary Results

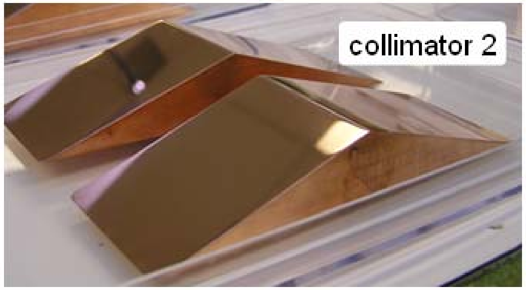
Theoretical predictions

Predictions from **earlier analytic calculations**, a **new 3D time domain (TD) numerical approach** (both shown right) and MAFIA/Gdfidl have been performed. It is noted that the new TD predictions for kick factors arising from geometric wakes differ significantly for collimators 2 and 3, even though they have identical taper angles and minimum apertures. Previously, it had been asserted that the geometric contribution to the measured kick would be identical for two such collimators and therefore the resistive wake could be inferred directly from their difference.

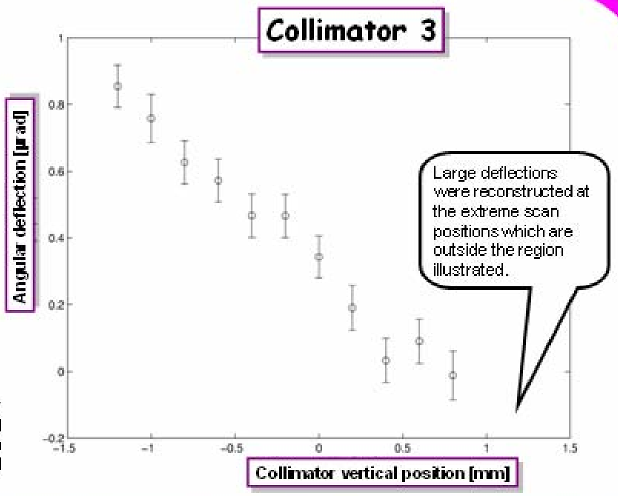
Collim. #	Geom. kick, V/pC/mm 3D calc. [?] σ_z=300 μm	Geom. kick, V/pC/mm 3D calc. [?] σ_z=500 μm	Geom. kick, V/pC/mm analytic calc. [?] σ_z=300/500 μm	Res. kick, V/pC/mm analytic calc. [?] σ_z=300 μm	Res. kick, V/pC/mm analytic calc. [?] σ_z=500 μm
1	1.9	1.7	2.2	0.005	0.004
2	3.6	3.1	4.6	0.011	0.008
3	6.1	5.1	4.6	2.5	2.0
4	0.74	0.77	0.6	0.001	0.001
5	7.1	6.8	4.6	0.018	0.014
6	2.9	2.3	4.6	0.10	0.077
7	3.1	2.7	4.6	0.021	0.016
8	3.0	2.4	4.6	0.023	0.017



Preliminary BPM calibrations, partial data sample, statistical errors only. In the near future with improved calibrations, resolution on the reconstructed kick factors of better than 0.1 V/pC/mm is anticipated with the data from this run.



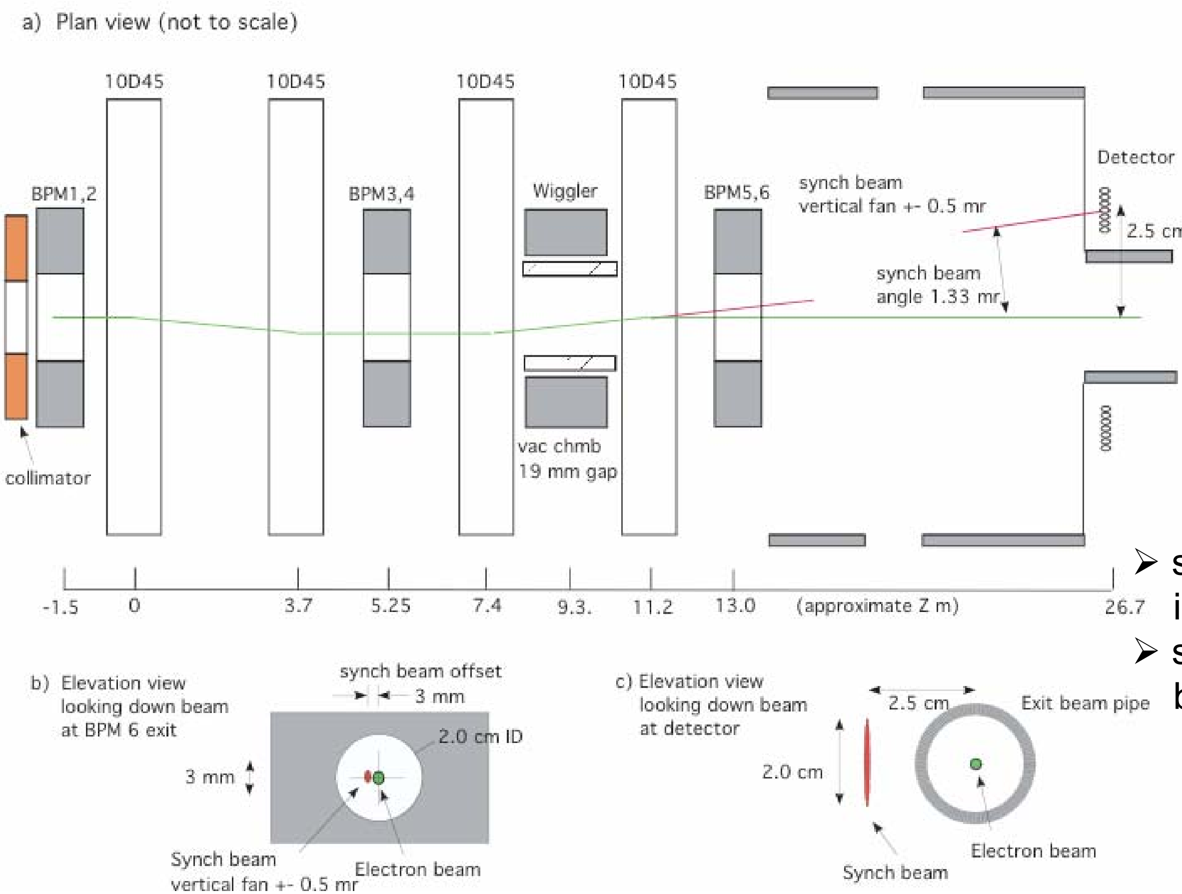
Typically **600 pulses** were recorded at 10 Hz for each of **12 vertical collimator positions**. Two reference orbit measurements were made immediately before and after each collimator scan to define the BPM offsets, without any collimator engaged in the beam position and with the collimator under test (nominally) symmetrically placed around the beam.



1000mm OFE Cu, ½ gap 1.4mm

T-474, T-475: Energy Spectrometers

- Precision energy measurements, 50-200 parts per million, needed for Higgs boson and top quark mass msmts
- BPM (T-474) & synch. stripe (T-475) spectrometers will be evaluated in a common 4-magnet chicane.
- These studies address achieving the ILC precise energy measurement goals: resolution, stability & systematics



<u>For BPM spectrometer</u>,
$\delta E/E$=100ppm $\rightarrow$ δx= 500nm, at BPMs 3-4
(same as for ILC design)

- ➢ study calibration procedure, which includes reversing the chicane polarity,
- ➢ study sensitivity to: beam trajectory, beam tilt, bunch length, beam shape, …

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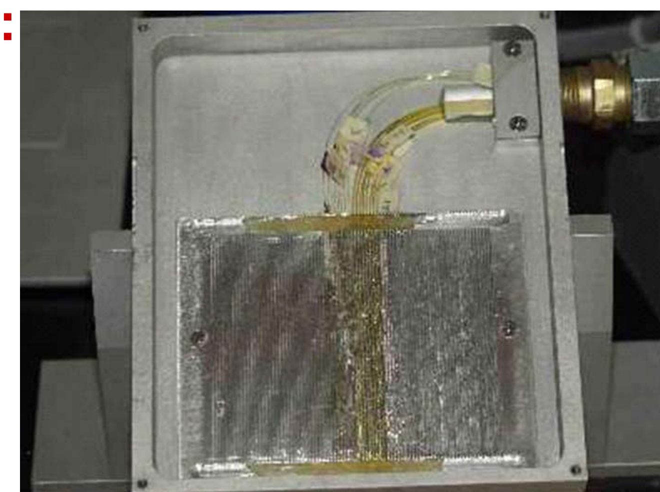
T-474 and T-475

T-474 BPM Energy Spectrometer:

PIs: Mike Hildreth (U. of Notre Dame) & Stewart Boogert (RHUL)

Collaborating Institutions:
U. of Cambridge, DESY, Dubna, Royal Holloway, SLAC, UC Berkeley, UC London, U. of Notre Dame

T-475 Synchrotron Stripe Energy Spectrometer:



PI: Eric Torrence (U. of Oregon)

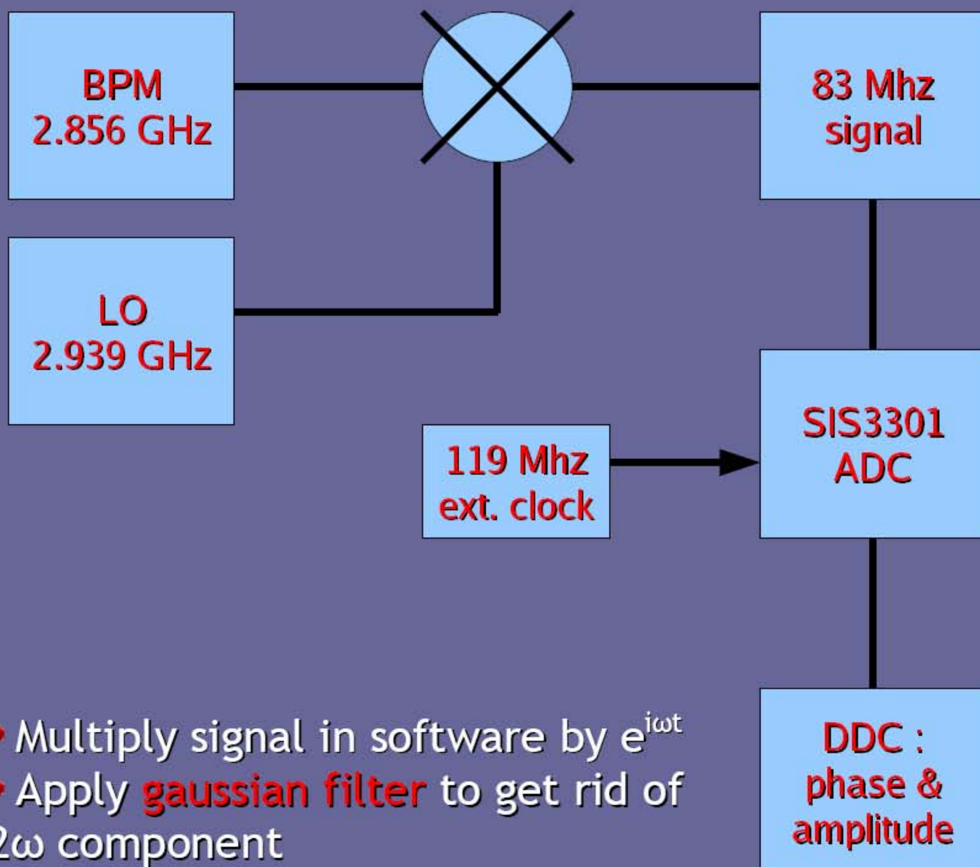
Collaborating Institutions: SLAC, U. of Oregon

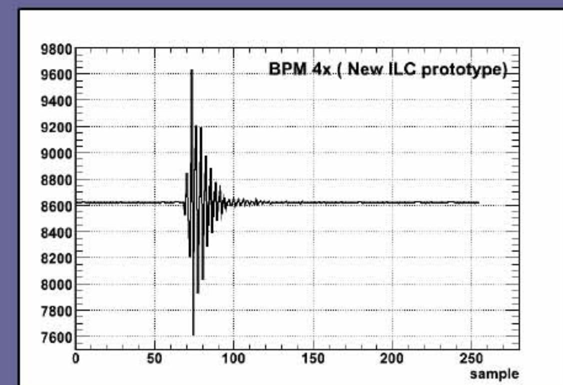
Prototype quartz fiber detector:

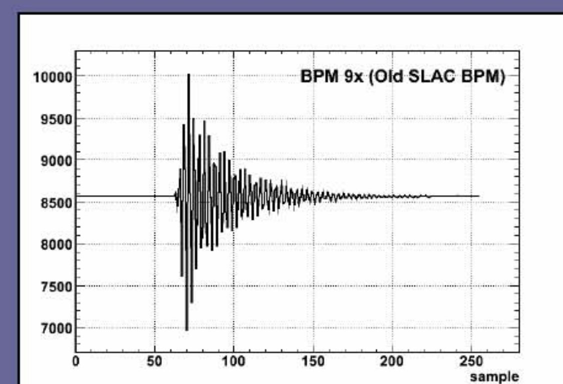
8 100-micron fibers + 8 600-micron fibers
w/ multi-anode PMT readout

BPM signal handling

from B. Maiheu, talk at Vancouver 2006 ALCPG







- Multiply signal in software by $e^{i\omega t}$
- Apply **gaussian filter** to get rid of 2ω component
- **Sample at fixed point** (t0Ref) to preserve linearity

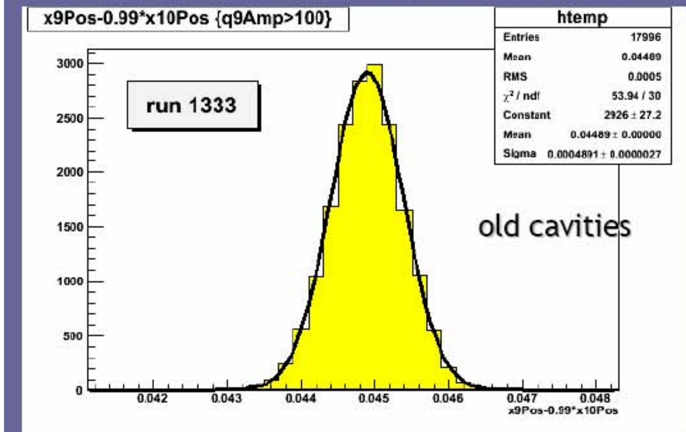
International Linear Collider
at Stanford Linear Accelerator Center

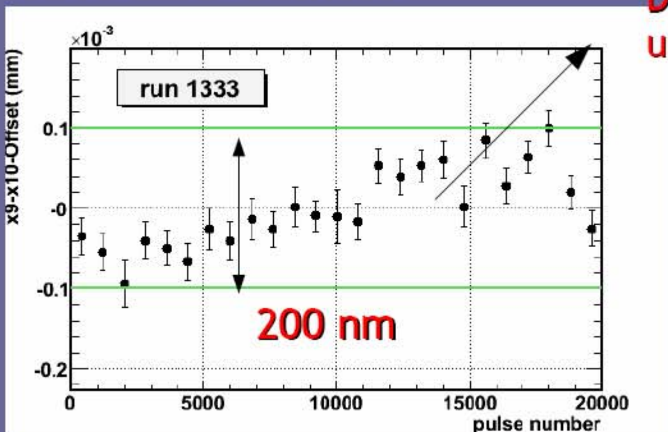
T-474

from B. Maiheu, talk at Vancouver 2006 ALCPG

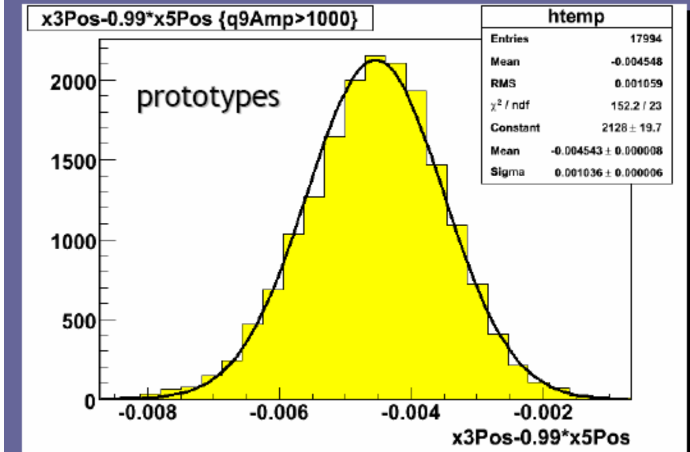
Resolution, stability over 30 min

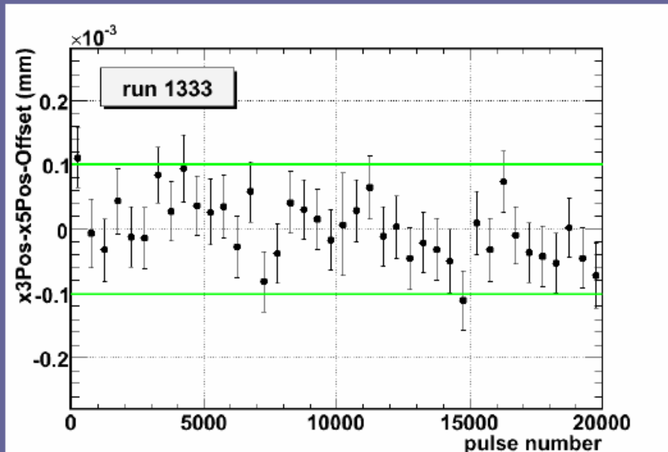
Drift : need to understand !!





Resolution 'out of the box' : BPM 3-5: ~ 700 nm in x, BPM 9-11: ~350 nm in x





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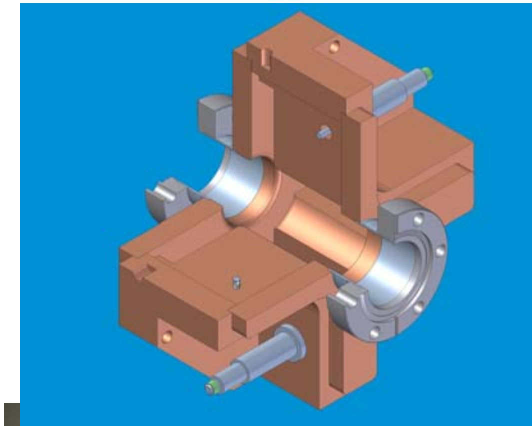
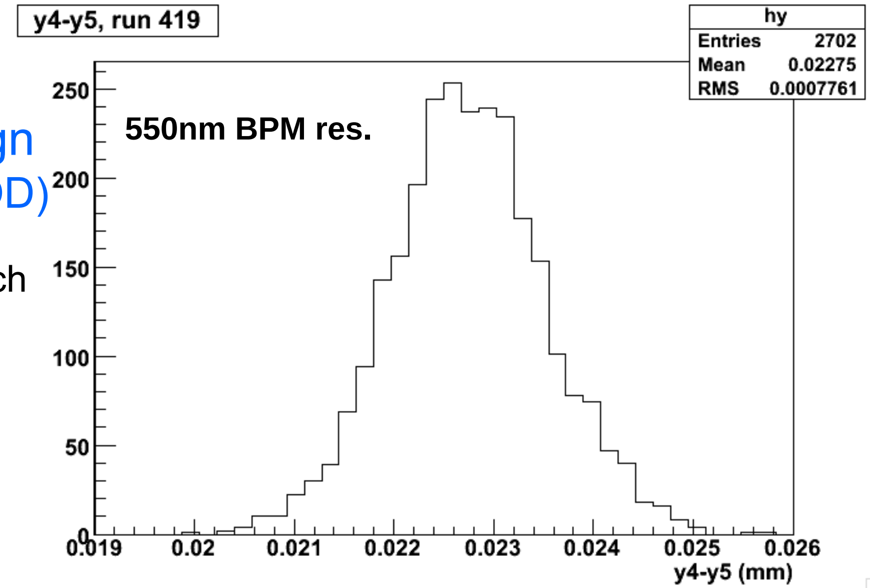
T-474 Prelim. Results

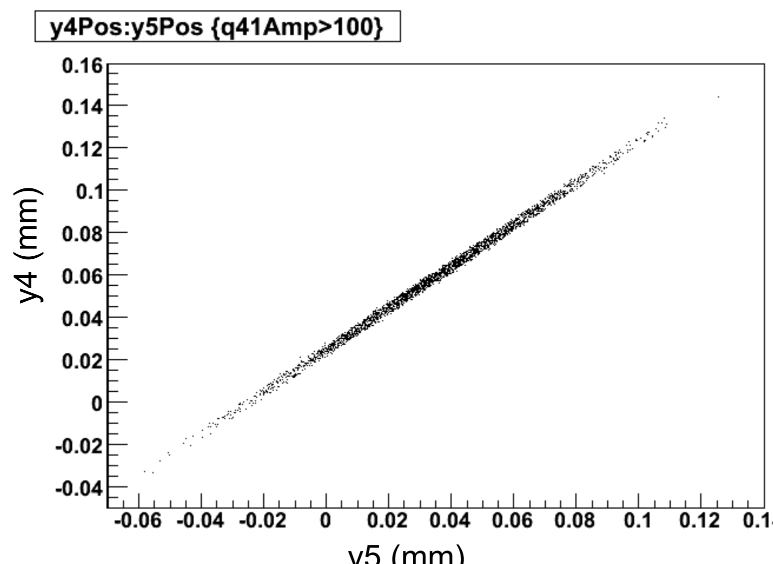
Resolution for new Linac BPM Prototype, 3BPM3-5



S-Band BPM Design (36 mm ID, 126 mm OD)

Q~500 for single bunch resolution





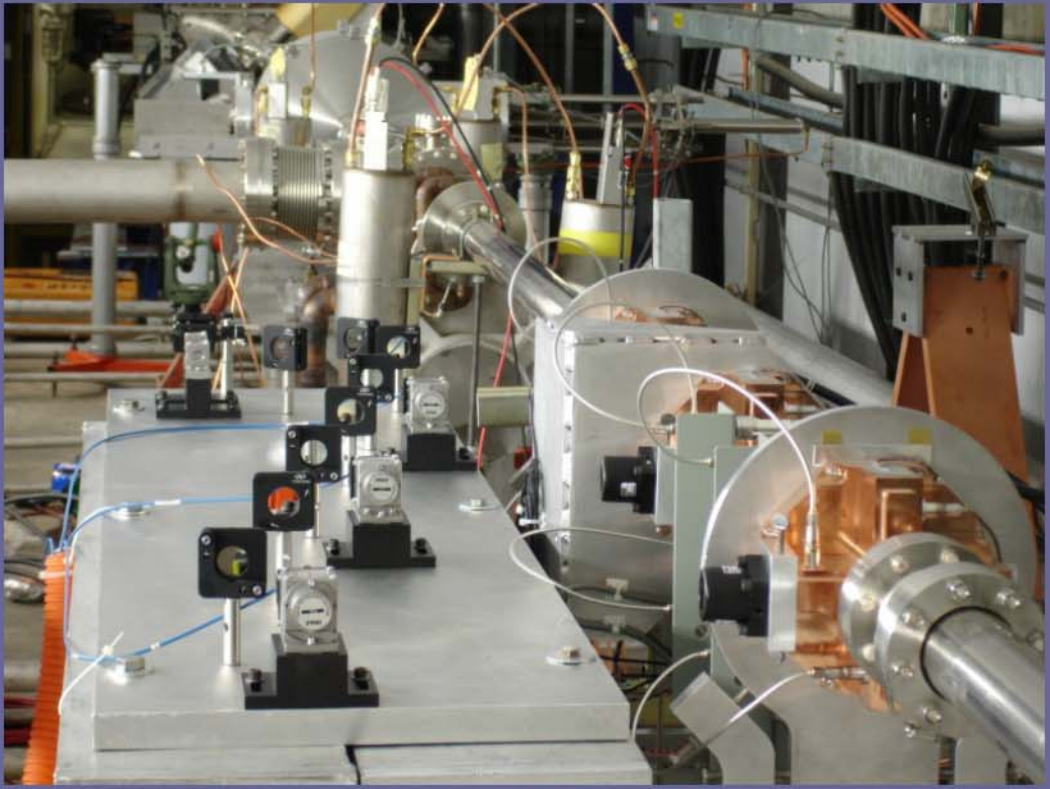
T-474

Interferometer

from B. Maiheu, talk at Vancouver 2006 ALCPG

M. Hildreth, M. Albrecht (Notre Dame)

- commissioned during July run
- sub nm resolution
- stability of < 30 nm (1 hr) with fixed mirror
- plan to link BPM stations



Beam RF effects at Colliders

SLC

Problem with EMI for SLD’s VXD3 Vertex Detector

- Loss of lock between front end boards and DAQ boards
- Solved with 10 μsec blanking around beamtime – front end boards ignore commands during this period

PEP-II

Heating of beamline components near IR due to High-order Modes (HOMs)

- S. Ecklund et al., *High Order Mode Heating Observations in the PEP-II IR*, SLAC-PUB-9372 (2002).
- A. Novokhatski and S. Weathersby, *RF Modes in the PEP-II Shielded Vertex Bellows,* SLAC-PUB-9952 (2003).
- Heating of button BPMs, sensitive to 7GHz HOM, causes BPMs to fall out

HERA

Beampipe heating and beam-gas backgrounds

- HOM-heating related to short positron bunch length

UA1

Initial beam pipe at IP too thin

- not enough skin depths for higher beam rf harmonics

Beam RF effects at ILC IR?

	SLC	PEP-II e^+	ILC
Electrons/Bunch, Q	4.0×10^{10}	5.0×10^{10}	2.0×10^{10}
Bunch Length, σ_Z	1 mm	12 mm	0.3 mm
Bunch Spacing	8 ms	4.2 ns	337 ns
Average Current	7 nA	1.7 A	50 μA
$(Q/\sigma_Z)^2$ relative	92	1	256

PEP-II experience

- HOM heating scales as $(Q/\sigma_Z)^2$
  - same scaling for EMI affecting detector electronics?
  - does scaling extend to mm and sub-mm bunch lengths?
  - need a cavity of suitable dimensions to excite
- IR geometry (aperture transitions, BPMs) has similar complexity as for ILC
- VXD and other readout systems ok for EMI in signal processing

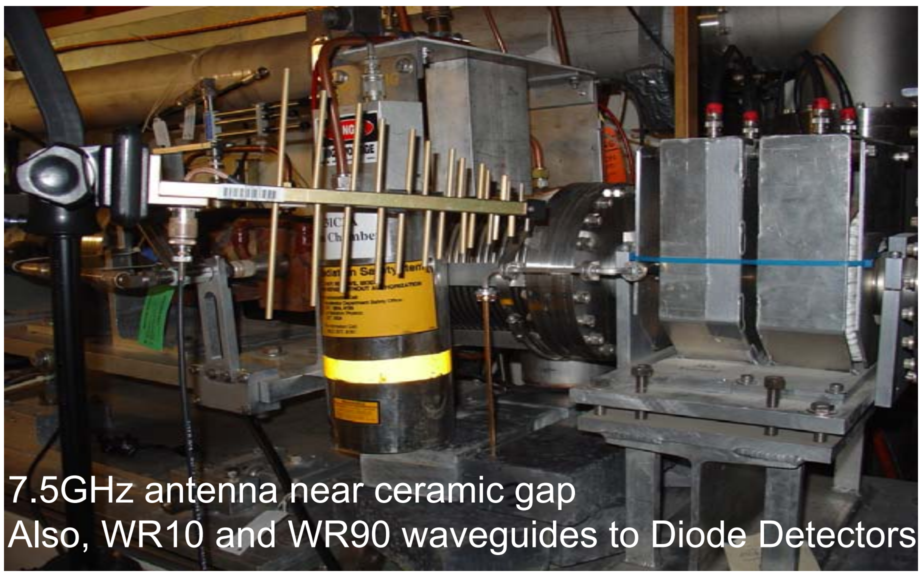
ILC Considerations

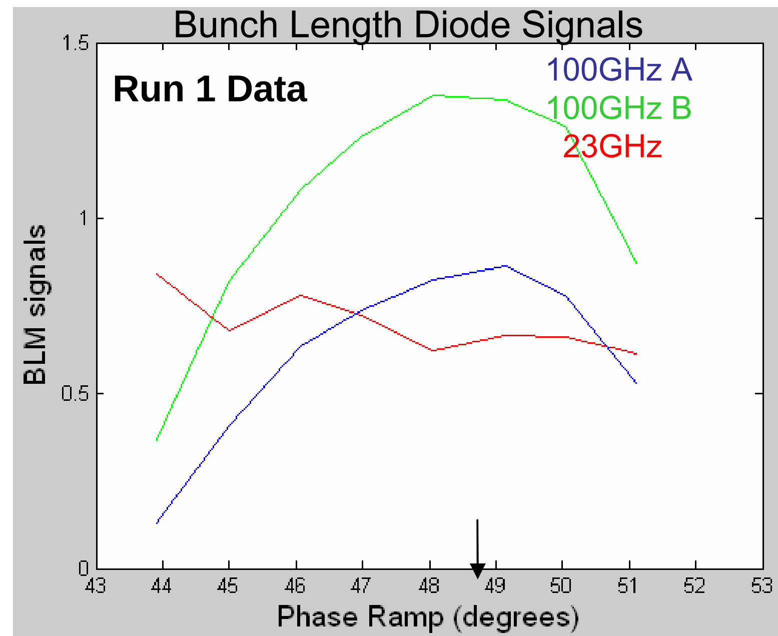
- HOM heating ok because of small average beam current
- EMI affecting Signal Processing and DAQ? Impact on Detector Design and Signal Processing Architecture?

EMI Studies in ESA

US-Japan funds; Y. Sugimoto (KEK), G. Bower (SLAC), N. Sinev (U. of Oregon)

- Characterize EMI along ESA beamline using antennas & fast 2.5GHz scope
- Measured dependence of EMI antenna signals on bunch charge, bunch length
  - Linear dependence on bunch charge
  - No dependence on bunch length (only see dependence for 100GHz detectors)
- Reproduced failure mode observed with SLD's vertex detector





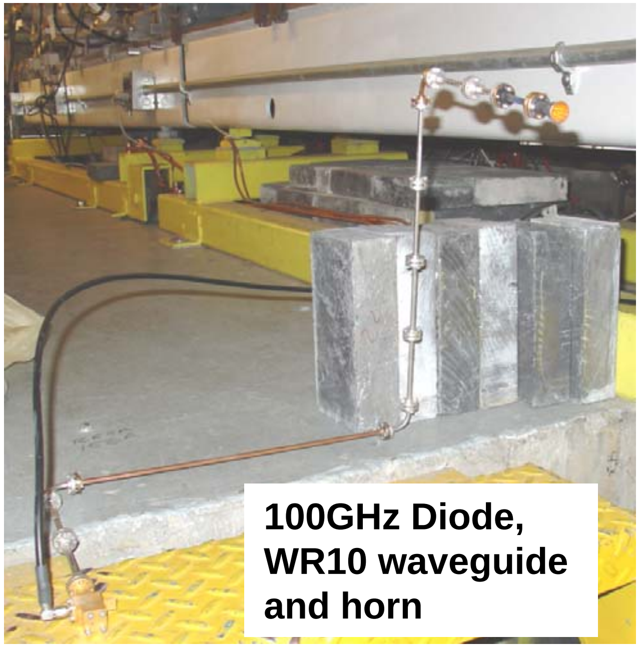
Bunch length has strong dependence on beam phase wrt Linac rf (phaseramp)

Radiated Power Spectrum

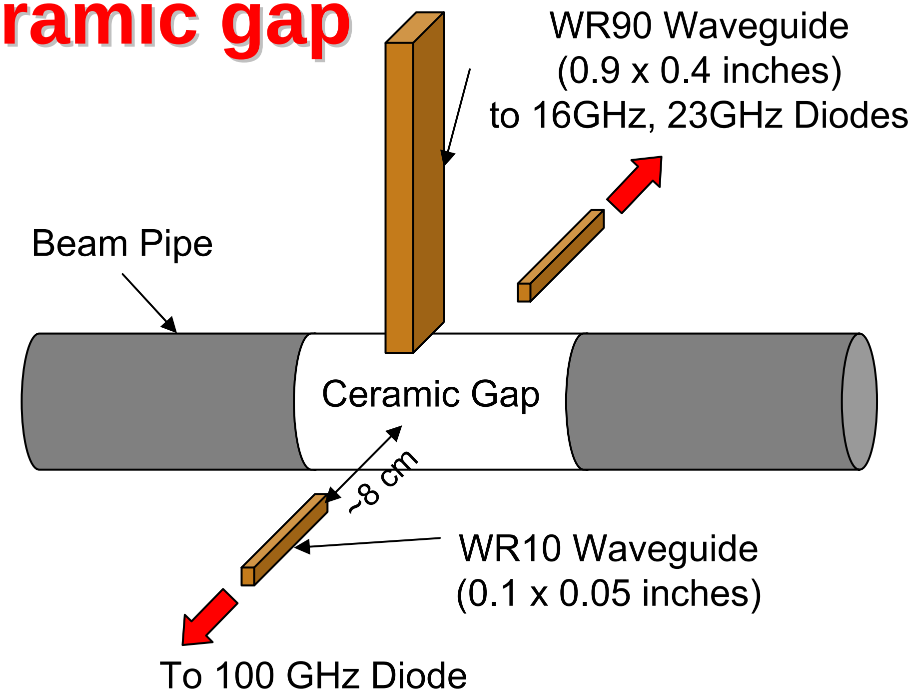
$$P(\omega) \propto Q^2 \cdot \exp\left(-\frac{\omega^2\sigma_z^2}{c^2}\right)$$

for σ_z=500um, 1/e decrease is at f=100GHz

Bunch length detectors at ceramic gap



100GHz Diode, WR10 waveguide and horn



WR10 and WR90 waveguides at ceramic gap

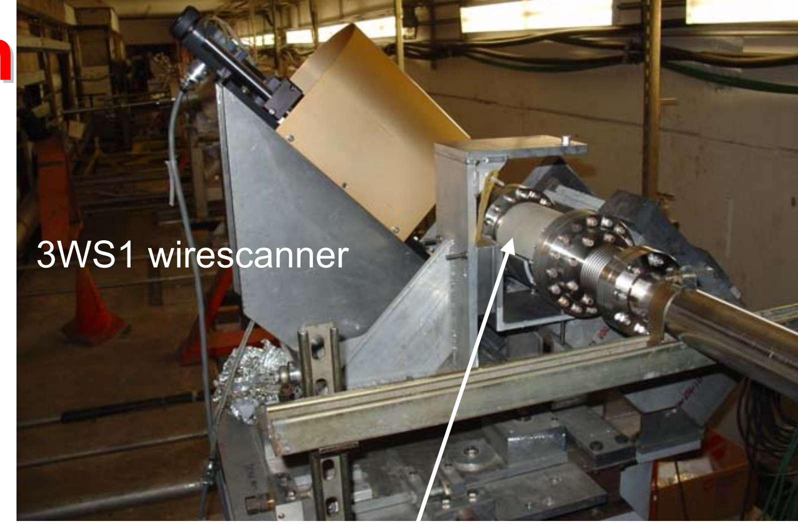
- too much signal on 100GHz diodes necessitated removing horn and backing waveguide ~4" away from ceramic gap
- WR90 waveguide also against ceramic gap; 30-meter length of this to 2 diode detectors in ChA

Radiated Power Spectrum

$$P(\omega) \propto Q^2 \cdot \exp\left(-\frac{\omega^2 \sigma_z^2}{c^2}\right)$$

for σ_z=500um, 1/e decrease is at f=100GHz

Bunch length msmts



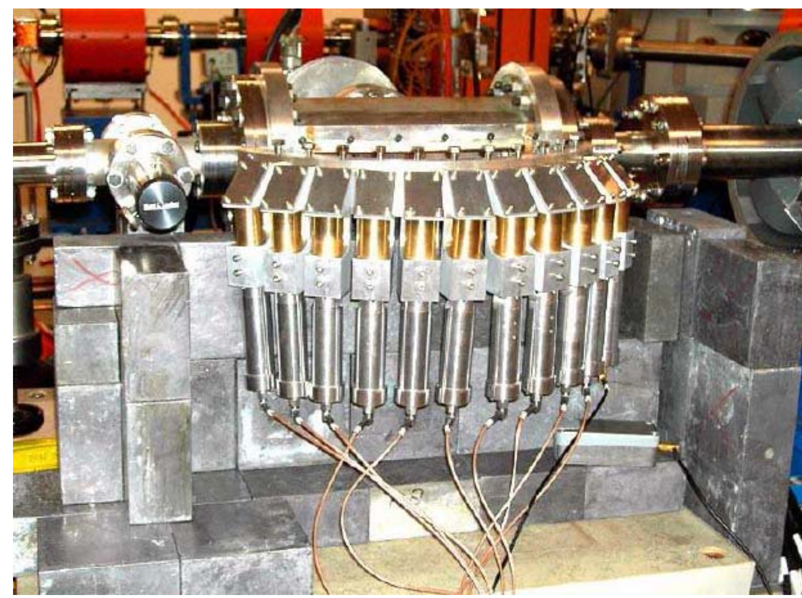
New ceramic gap for July ’06 Run

For July ’06 Run:

- additional broadband pyroelectric detectors at new ceramic gap
  - many iterations to improve signal:noise, shielding gap except for collecting horn to detector
  - sensitive to shorter bunches than 100GHz detector
- used transverse “LOLA” cavity at end of Linac to measure bunch length and E-z correlation of bunch (see next slide)

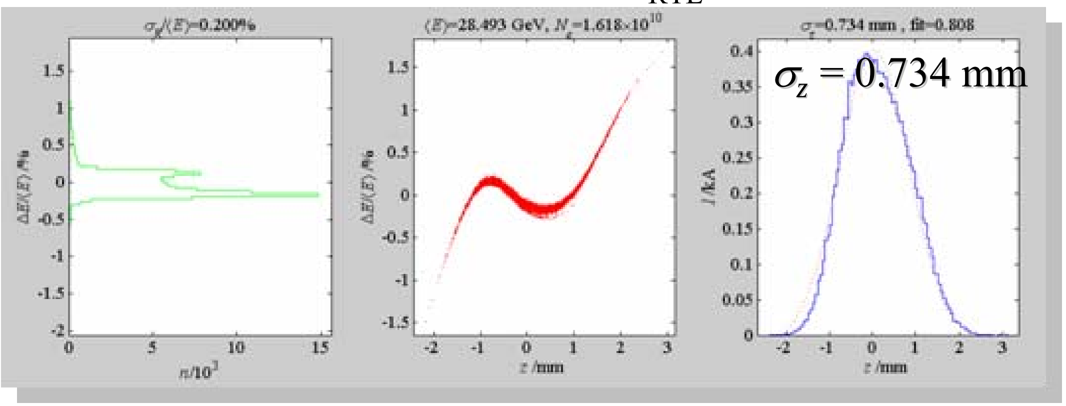
T-487 in FY07

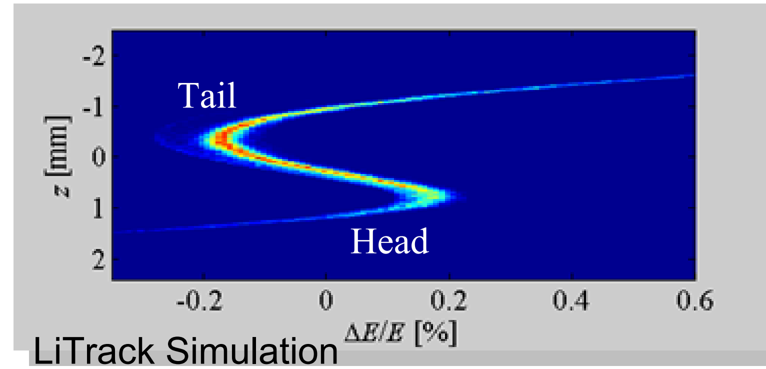
- array of 11 pyroelectric detectors to measure frequency spectrum of Smith-Purcell radiation (coherent radiation from beam passing close to periodic structure), to allow determination of bunch longitudinal profile
- PI is G. Doucas at U. of Oxford



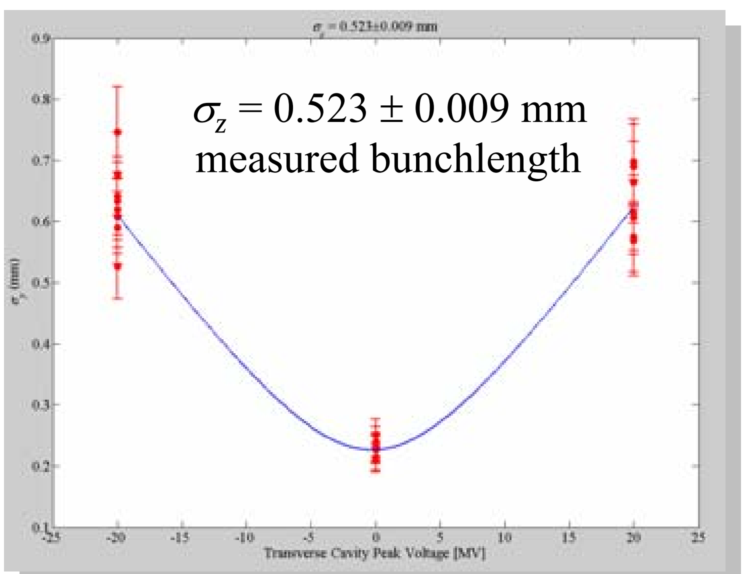
Bunchlength + Energy-Z correlation Measurements at end of Linac with Transverse "LOLA" cavity

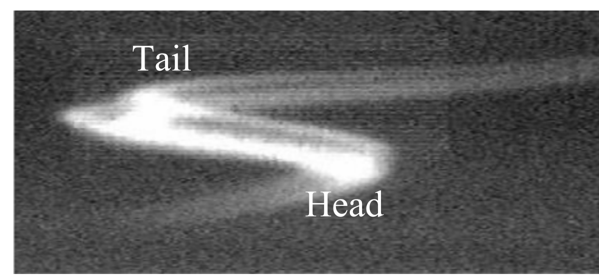
LiTrack Simulation: Linac RF phase = -10 deg,
$N = 1.6\text{E}10$, $V_{RTL} = 38.5$ MV





LiTrack Simulation





A-Line Synchrotron Light Monitor signal w/ LOLA on. 1-m dispersion for horizontal axis. Calibrated vertical scale to be 0.32mm/deg; 1deg at S-band ~300um.

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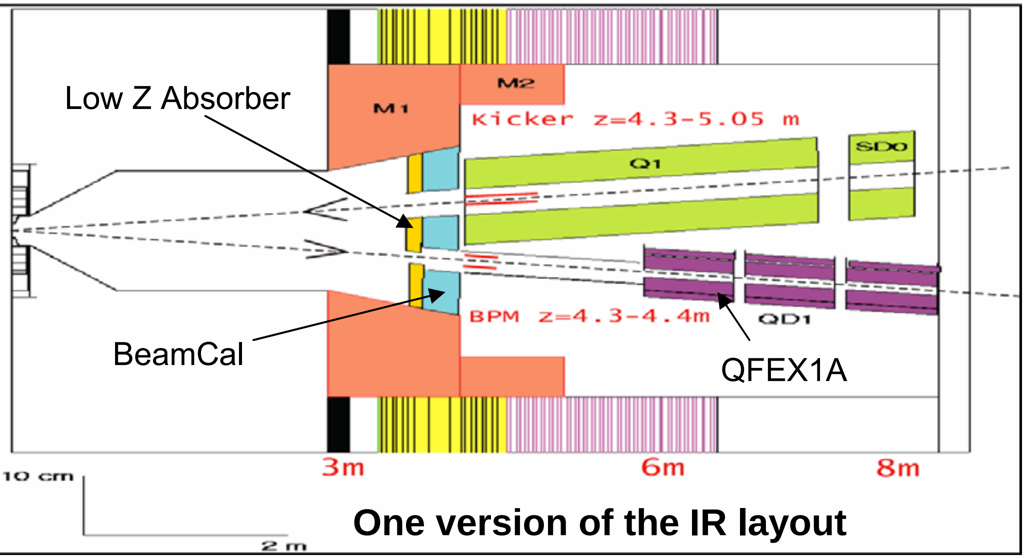
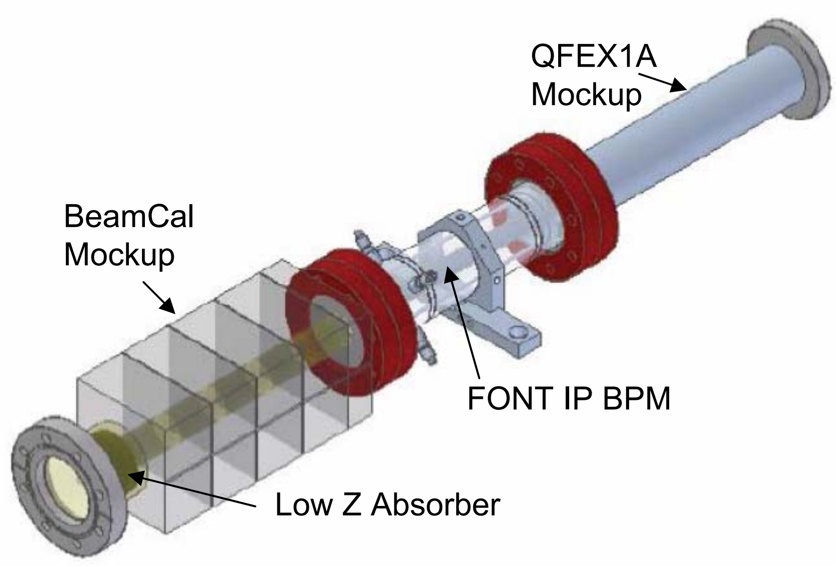
T-488: IR Mockup in ESA for FONT IP BPM studies

PI: Phil Burrows, U. of Oxford
Collaboration: U. of Oxford, Daresbury Lab, SLAC

- stripline IP BPM commissioned & calibrated with primary beam
- simulate ILC pairs hitting components in forward region of ILC Detector near IP bpms, exceeding maximum ILC energy density of 1000 GeV/mm^2 by up to factor 100

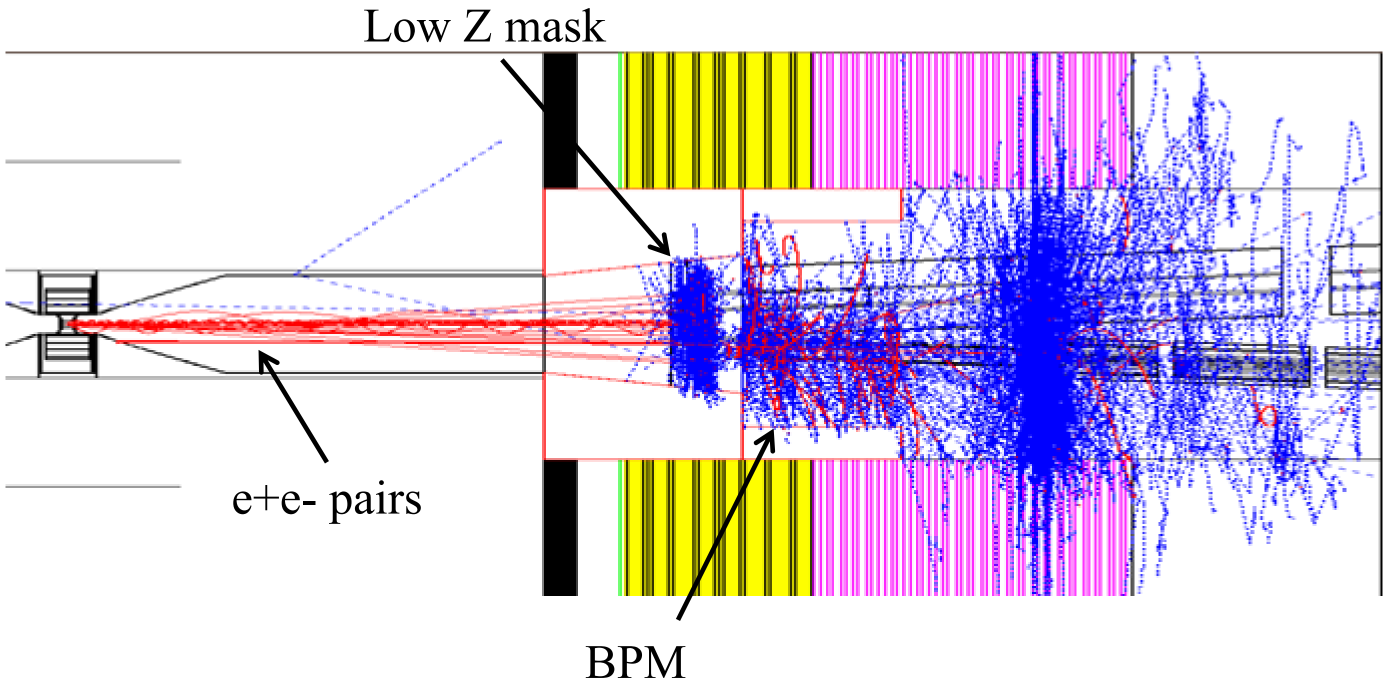


One version of the IR layout

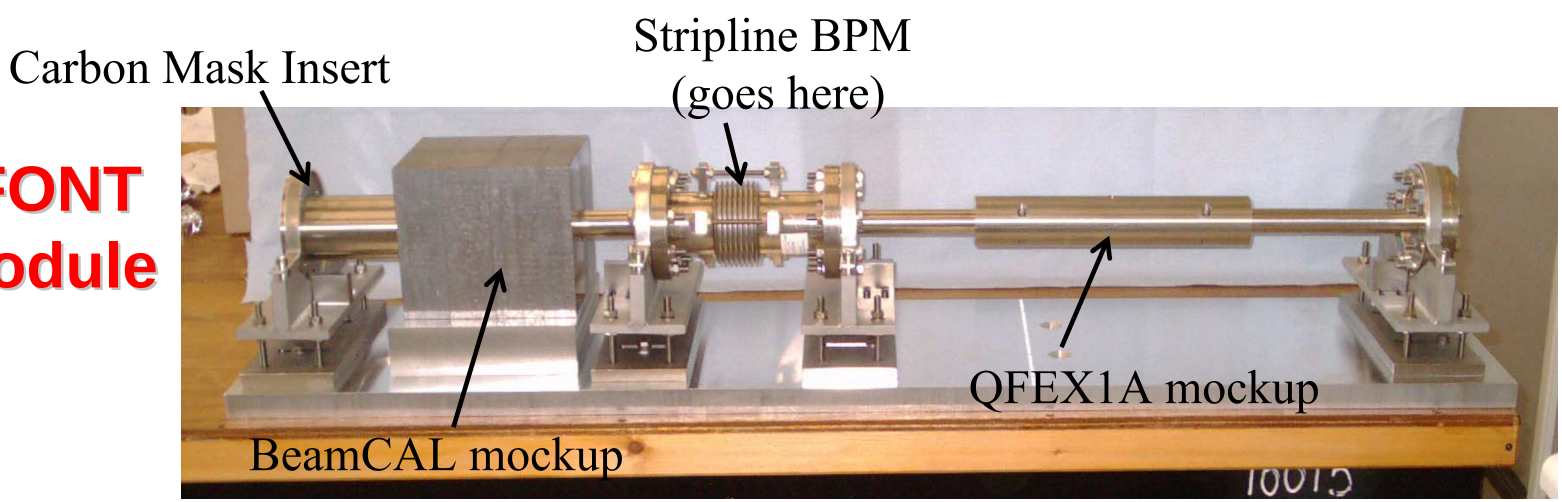


"BPM Module" for ESA Tests

Pair-induced EM backgrounds



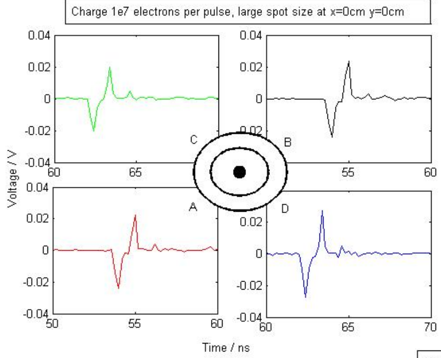
T-488 FONT Test Module

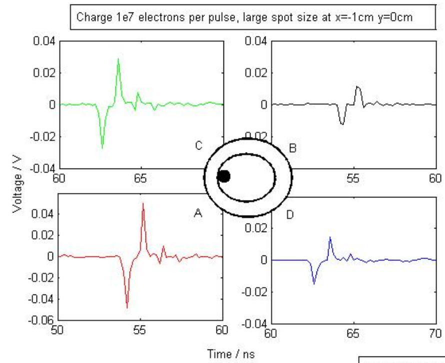


T-488 Prelim. Results

Beam scan across module

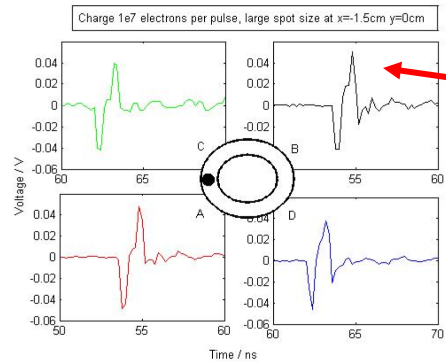
12-Jul-06 data



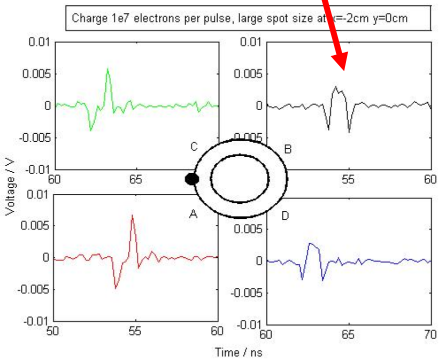


10^7 e-/bunch,

1mm rms spotsize



Noticeable degradation of signals



Scintillator viewed by ccd camera for profile monitor. Central square is 1cm x 1cm. (starry sky background from radiation damage to pixels)

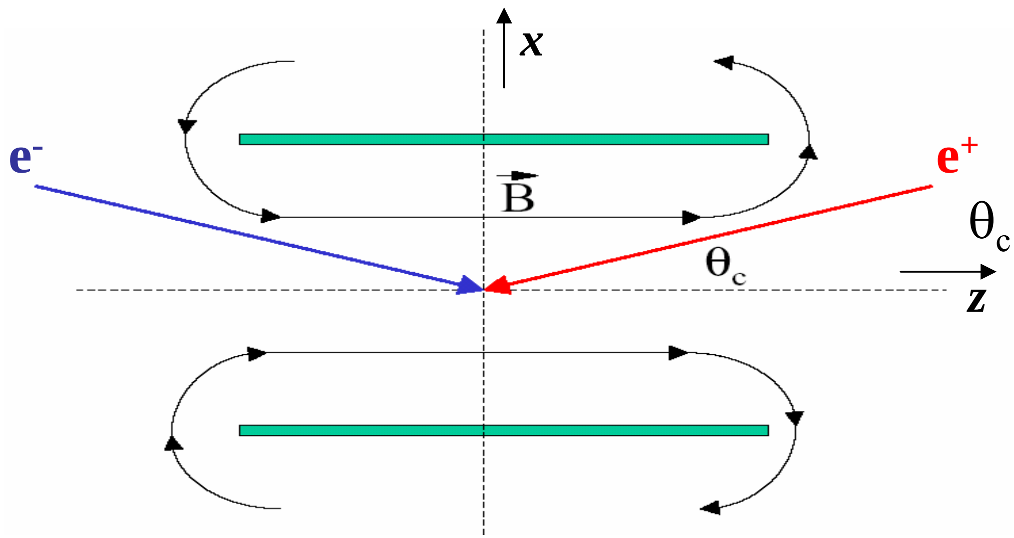
Aug. 29, 2006

Summary Remarks

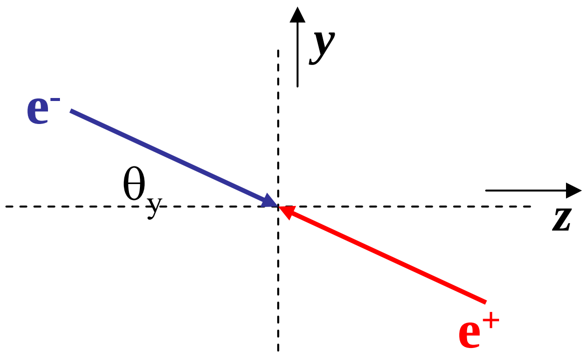
- **MDI encompasses a broad range of topics** involving ILC RDR work, Detector concepts, MDI Panel, GDE
- **MDI studies impact ILC design choices**: examples include IR and Linac crossing angles, 1 IR vs 2 IR, IR magnet design, ILC options for e^+ polarization, e^-e^-, γ-γ
- **Collimation & Backgrounds**: critical to achieving design luminosity; many ILC and detector parameters, many detailed studies needed
- **Precise Beam Instrumentation** measurements needed, in particular for (L,E,P) measurements
- **Forward Region Detectors** important for luminosity tuning and precise luminosity msmts, + for SUSY studies and identifying 2-photon bkgds
- **Important beam test program underway at SLAC's End Station A** (collimator wakefields, E-spectrometers, backgrounds & EMI, σ_Z msmts)
- +, not discussed in this talk, very important test beam program underway at **ATF facility at KEK**, and in the future there with **ATF2**: beam instrumentation, feedback and controls, tuning procedures to achieve small 35-nm spotsizes with <10-nm stability

IP Crossing Angle and Solenoid Effects

e^+e^- collisions:



θ_c = 10 mrad



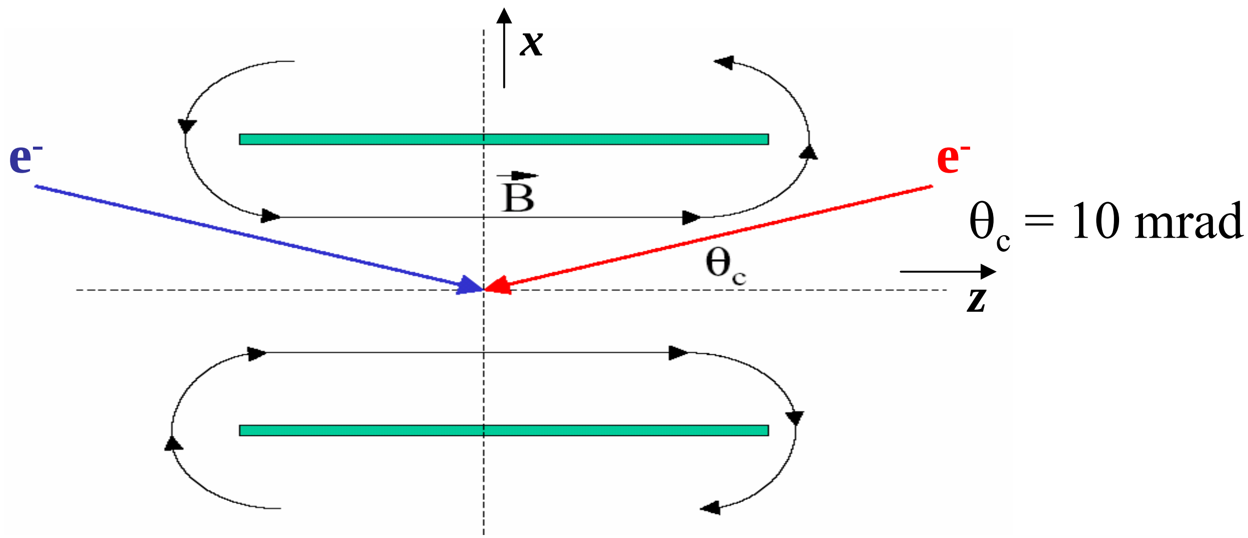
Beams still collide head-on

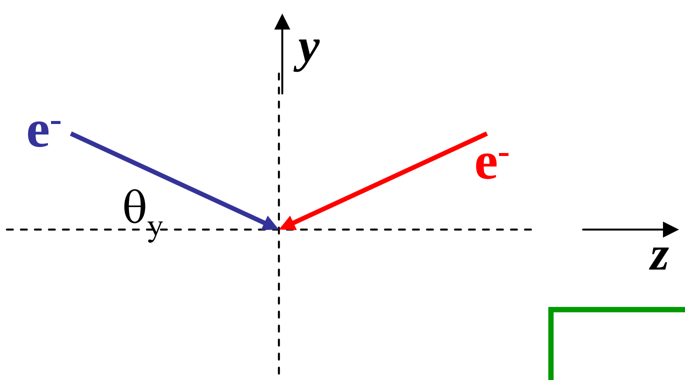
SiD with B = 5T, $\theta_y \sim 100\ \mu$rad

(Reference: A. Seryi and B. Parker, LCC-143)

IP Crossing Angle and Solenoid Effects

e⁻e⁻ collisions:





Beams collide with vertical θ_C

SiD with B = 5T, $\theta_y \sim 100\ \mu$rad

(Reference: A. Seryi and B. Parker, LCC-143)

Significant Luminosity loss,
unless additional compensation provided!

IP Crossing Angle and Solenoid Effects

Spin precession and misalignment of Compton IP to collider IP:

- will have ~100 μrad bend angle between Compton IP (upstream or downstream) and collider IP
- angle is small compared to disruption angles, but still undesirable

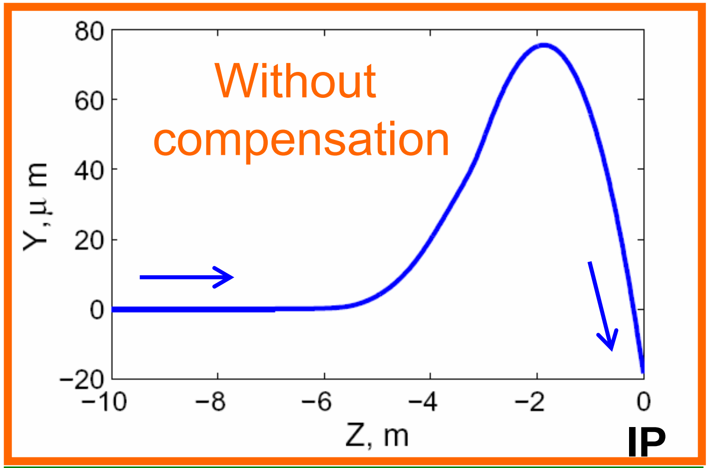
Three reasons to compensate the resulting vertical steering :

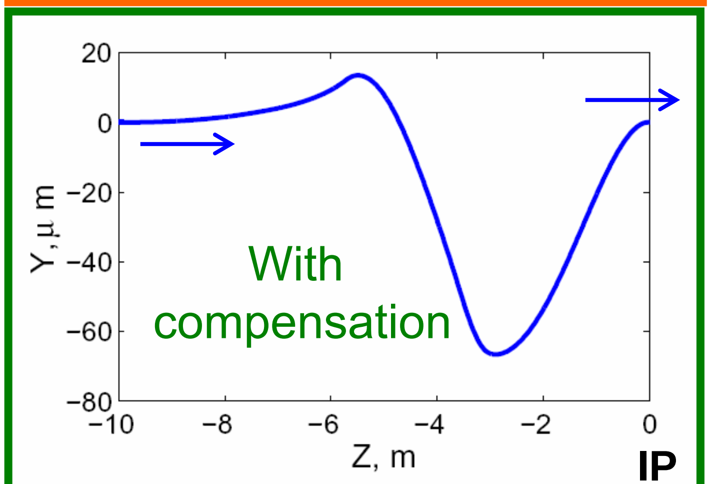
- want no vertical crossing angle for e^-e^- collisions
- alignment of extraction line should be energy-independent
- want no net bend angle wrt upstream or downstream polarimeters

Compensation techniques:

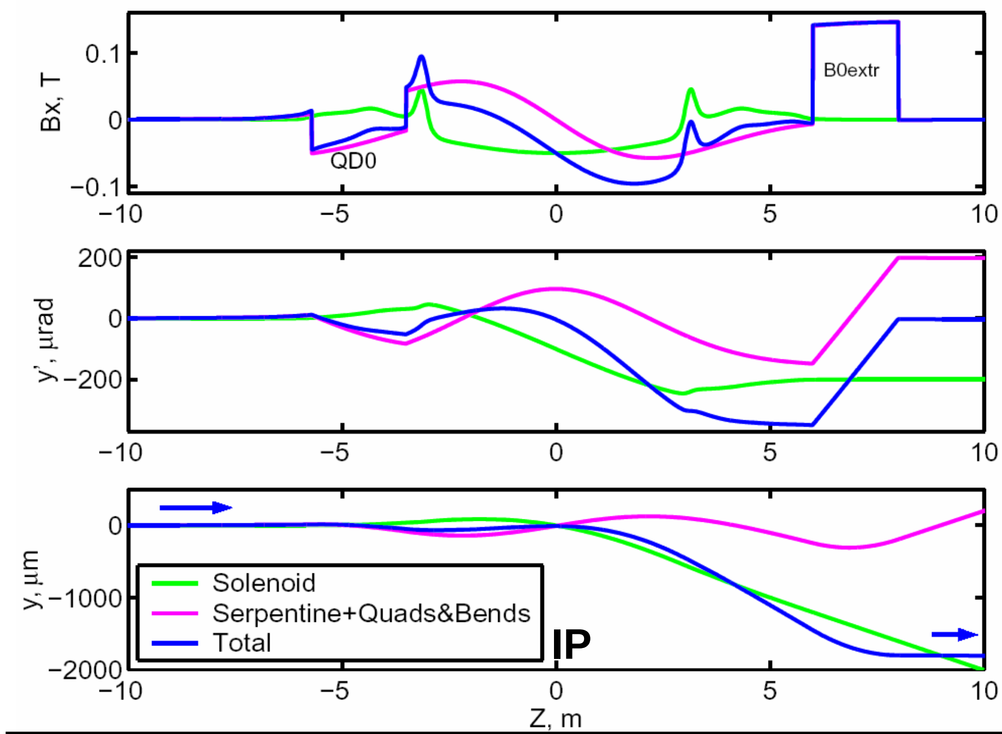
- additional vertical bends
- serpentine solenoid winding (add vertical bend to solenoid field; BNL work)

Compensation of Solenoid Steering Effects w/ Crossing Angle





The IP angle can be compensated by the Detector Integrated Dipole (Serpentine) Corrector and offsets of QD0 and QF1



The Serpentine increases transverse field seen by the outgoing beam and pairs. The extraction angle can be compensated by external dipoles.

- Adds ~ 0.01 of B_z along x in detector
- TPC tracking → map B_z to 0.0005 to control distortions
- Larger backgrounds and steering of the spent beam; steering compensated with external dipoles